SECTION 7

SITE CHARACTERIZATION OF SWMU 17 AND SWMU 40 (CONTAMINATED WASTE BURNING AREAS AND SANITARY LANDFILL)

7.1 HISTORY AND OPERATIONS

7.1.0.1. SWMU 17 is used for burning wastes potentially contaminated with explosives or propellants and is subdivided into five separate areas (A through E) based on history and operations. The general SWMU 17 (Vicinity) discussions address the monitoring wells placed in and around the unit and the groundwater discharge point at the New River as determined by the dye tracing study. The discharge point is approximately 4,800 feet west of the SWMU 17 boundary. SWMU 40 is included with SWMU 17 because of their proximity and similar subsurface conditions.

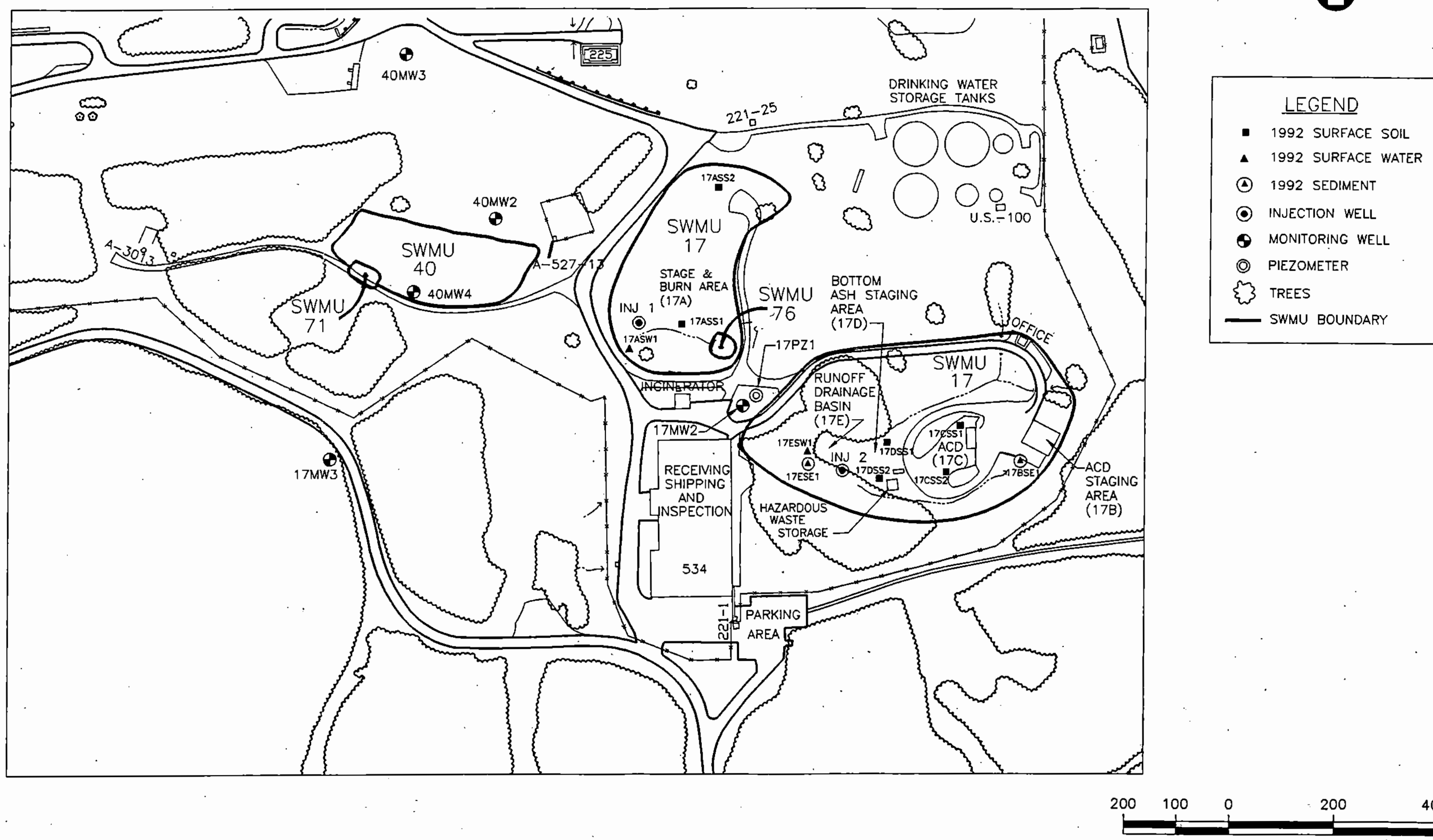
7.1.0.2. SWMU 17 is located in the south-central part of the Main Manufacturing Area. Plate 1 shows SWMU 17 and SWMU 40 in relation to the rest of the facility. A detailed location map of SWMU 17/SWMU 40 is presented as Figure 7.1.

7.1.1 SWMU 17A: Stage and Burn Area

7.1.1.1. SWMU 17A is situated within the westernmost of the two prominent sinkholes which form the dominant geomorphological feature of SWMU 17. The sinkhole is approximately 30 feet deep by 200 feet wide by 400 feet long.

7.1.1.2. Materials consisting mostly of large metallic items and large combustible items contaminated with propellants and explosives are accumulated into large piles in the Stage and Burn Area. The materials are piled on the ground by crane to a height of approximately 30 feet and then ignited. Facility representatives reported that waste oil and diesel fuel are used to fuel the burning operations. Wood, paper, and cardboard contaminated with propellants and explosives are often added to the piles to increase combustion. Waste oil used for these operations was stored in the two waste oil USTs (SWMU 76 on Figure 7.1) formerly located along the Stage and Burn Area embankment east of the waste pile. Following burning of the waste pile, scrap metal is removed from the

FIGURE 7.1
SWMU 17/SWMU 40 LOCATION MAP (CONTAMINATED WASTE BURNING AREA)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



2843F7_1 10/2/95

PARSONS ENGINEERING SCIENCE, INC.

residue and accumulated in piles to be sold for recycling. If ash is characterized as hazardous it is transported off-post for proper disposal. Non-hazardous ash is shipped off-post to an industrial landfill. When the USTs were removed in 1991, lead slag was detected in soils at the SWMU 76 area. This unnumbered SWMU was identified as the Former Lead Furnace Area (FLFA), a facility used at the time of World War II.

7.1.2 SWMU 17B: Air Curtain Destructor (ACD) Staging Area

7.1.2.1. SWMU 17B (as well as 17C, 17D, and 17E), is located within the easternmost sinkhole of SWMU 17. The sinkhole is approximately 40 feet deep by 600 feet long by 350 feet wide. SWMU 17B is a staging area for the ACD. It is divided into two bays; one is covered with a roof and the other is open. Both are constructed with concrete floors and 6-foot high concrete walls on three sides. Materials are accumulated in this staging area prior to burning in the ACD. Adjacent to the uncovered storage bay is a below-grade, concrete-lined settling basin that collects surface water runoff from the staging pads. The pit is equipped with a sump pump that, at one time, peridocially pumped the collected water into an unlined drainage ditch leading to the Runoff Drainage Basin (17E). Currently, runoff is collected in a sump and treated at RAAP's industrial sewage treatment plant.

7.1.3 SWMU 17C: Air Curtain Destructor (ACD)

7.1.3.1. Contaminated wastes small enough to feed into the burn chamber are burned in the ACD (17C), a large concrete pit enclosed within a metal structure. Forced air blowers increase burning efficiency. The system does not qualify as an incinerator under EPA definitions and is considered simply a form of controlled open burning (USAEHA, 1980).

7.1.4 SWMU 17D: Ash Staging Area

7.1.4.1. SWMU 17D is a staging area adjacent to the ACD. It is used for accumulating and storing ACD ash and scrap metal prior to disposal. The staging area is currently composed of a storage shed with a concrete floor. Prior to construction of the shed, the ash and scrap metal were staged on the ground.

7.1.5 SWMU 17E: Runoff Drainage Basin

7.1.5.1. Directly west of the ACD Ash Staging Area (17D) is SWMU 17E. It is an unlined settling basin. This unit appears to be a natural drainage depression rather than a constructed basin. Surface water runoff from the ACD and Ash Staging Area drains into SWMU 17E; water from the settling basin at SWMU 17B also discharges to this drainage basin.

7.1.6 SWMU 40: Sanitary Landfill

7.1.6.1. This SWMU was identified in the RCRA Facility Assessment (USEPA, 1989) as having a potential for releasing contaminants into the environment and was included in the RCRA Permit for Corrective Action and Incinerator Operation (USEPA, 1989) as warranting investigation. SWMU 40 is a Sanitary Landfill (Nitroglycerin Area) located in the south-central section of the RAAP Main Manufacturing Area. It is situated about 200 feet west-northwest of the Contaminated Waste Burning Areas (SWMU 17). This landfill was never permitted, and was reportedly used in the 1970s and early 1980s (following closure of SWMU 43) for the disposal of uncontaminated paper, municipal refuse, cement, and rubber tires (USEPA, 1987; USATHAMA, 1976). No known hazardous wastes or wastes containing hazardous constituents were ever disposed of in the landfill.

7.1.6.2. The landfill is approximately 430 feet by 100 feet in size (about 1 acre). The unit was an area fill; no trenches were excavated. The unit was closed with a soil cap and moderate grass cover. Since closure, excavated "clean" soils have been stockpiled on top of the unit by the USACE as a result of construction activities at RAAP. In 1991 and 1992, a fenced enclosure for asbestos storage and other hazardous materials was constructed near the northeast corner of this SWMU.

7.2 PREVIOUS INVESTIGATIONS

7.2.0.1. Initial RFI activities were conducted at SWMU 17 between Fall 1991 and Spring 1992, and VI activities were performed at SWMU 40 in Fall 1991. The findings of the RFI program for the five different areas in SWMU 17 (Dames & Moore, 1992a) and the VI results for SWMU 40 (Dames & Moore, 1992b) are discussed below. Results of soil, surface water and sediment sampling for the five SWMU 17 areas are summarized in Tables 7.1, 7.2, and 7.3, respectively. Also included in these summary tables for comparison are

TABLE 7.1
RFI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR SOIL SAMPLES COLLECTED AT SWMU 17
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 26 Feb 92 - 27 Feb 92 1.0 ft - 2.8 ft	Upland Soil Background Comparison Level*	HBN	RBC Industria Soil
TAL Inorganics (µg/g)						
Aluminum	14.1	8	7,170 - 37,600	22,921	230,000	1,000,00(
Antimony	20	8	LT 7.14 - 22.9	7.14	30	410
Arsenic	30	8	[5.55] - [100]	9	0.5	1.6
Barium	1	8	39.3 - [1,120]	109	1,000	72,000
Beryllium	0.2	8	LT 0.5 - [2.11]	1.10	0.1	0.67
Cadmium	2	8	LT 0.7 - 10.2	0.70	40	510
Calcium	100	8	1,460 B - 130,000	109,994	NSA	NA
Chromium	4	8	25.8 - 210	47.46	400	1,000,000*
Cobalt	3	8	[7.83] - [27.5]	27.90	0.8	NA
Copper	7	8	16.6 - [4,000]	29.69	2,900	38,000
Iron	1,000	8	18,500 - 110,000	39,707	NSA	NA
Lead	2	8	16.2 - [1,990]	282.84	200	NA
Magnesium	50	8	5,270 - 92,000	45,931	NSA	NA
Manganese	0.275	8	200 - 901	978	8,000	5,100
Mercury	0.1	8	LT 0.05 - 0.569	0.05	20	310
Nickel	3	8	9.7 - 120	37.23	1,000	20,000***
Potassium	37.5	8	523 - 8,580	3,864	NSA	NA
Silver	4	8	1.07 - 23	1.75	200	5,100
Sodium	150	8	180 B - 3,240	313.20	NSA	NA
Thallium	20	8	LT 6.62 - [79]	6.62	6	NA
Vanadium	0.775	8	27.9 - 69.1	73.89	560	7,200
Zinc	30.2	8	63.1 - 11,000	373.56	16,000	310,000
Explosives (µg/g)						
24DNT	0.424	8	0.963 - LT 0.424	1	NT	2,000

* Upland soil samples were collected from 5 locations at RAAP. The mean and standard deviations were calculated. Background comparison levels wer selected from the upper 95 percent confidence interval of the background data set, which is equal to the mean plus two standard deviations.

** Chromium III and compounds

*** Nickel (soluble salts)

B Analyte was detected in corresponding method blank; values are flagged if the sample concentration is less than 10 times the method blank concentratio for common laboratory constituents and 5 times for all other constituents.

HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumption consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).

LT Concentration is reported as less than the certified reporting limit.

NA Not available; no RBC provided

NSA No standard (HBN) available; health effects data were not available for the calculation of an HBN. HBNs were not derived for TICs.

NT Not tested.

PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given anaytical method.

RBC Risk-based concentration provided by USEPA (USEPA,1994)

TAL Target analyte list.

µg/g Micrograms per gram.

[ ] Brackets indicate that the detected concentration exceeds the HBN.

From Dames & Moore, 1992a

TABLE 7.2
RFI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR SURFACE WATER SAMPLES COLLECTED AT SWMU 17
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 27 Feb 92 - 05 Mar 92	HBN	RBC Tap Water
TAL Inorganics (μg/L)					
Aluminum	141	3	4,000 - 21,000	101,500	110,000
Arsenic	10	3	[59.2] - [96.3]	50	0.038
Barium	20	3	86.9 - 175	1,000	2,600
Calcium	500	3	30,200 - 47,400	NSA	NA
Chromium	10	3	[52.9] - [156]	50	180*
Copper	60	3	266 - 682	1,295	1,400
Iron	38.1	3	3,940 - 31,200	NSA	NA
Lead	10	3	[150] - [520]	50	NA
Magnesium	500	3	7,800 - 25,700	NSA	NA
Manganese	2.75	3	67.7 - 339	3,500	180
Mercury	2	3	0.236 - 0.383	2	11
Nickel	50	3	LT 34.3 - 44.5	700	730**
Potassium	375	3	8,330 - 11,400	NSA	NA
Silver	2	3	0.396 - 1.25	50	180
Sodium	500	3	14,400 - 32,000	NSA	NA
Vanadium	40	3	LT 11 - 68.7	245	260
Zinc	50	3	624 - 1,700	7,000	11,000
Explosives (μg/L)					
24DNT	0.064	3	[0.092] - [0.372]	0.05	73
Other (μg/L)					
Total Organic Carbon	1,000	3	9,330 - 12,900	NSA	NA
Total Organic Halogens	1	3	44.9 - 96.5	NSA	NA
pH	NA	3	7.41 L - 7.71	NSA	NA

* Chromium VI and compounds.
** Nickel (soluble salts).
HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumptions consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
L Indicates holding time for analysis was missed, but data quality is not believed to be affected.
LT Concentration is reported as less than the certified reporting limit.
NA Not available.
NSA No standard (HBN) available; health effects data were not available for the calculation of an HBN. HBNs were not derived for TICs.
PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given anaytical method.
RBC Risk-based conentration provided by USEPA (USEPA, 1994).
TAL Target analyte list.
μg/L Micrograms per liter.
[ ] Brackets indicate that the detected concentration exceeds the HBN and/or RBC.
From Dames & Moore, 1992a

TABLE 7.3
RFI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR SEDIMENT SAMPLES COLLECTED AT SWMU 17
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 27 Feb 92 - 05 Mar 92 0.5 ft - 1.0 ft	Upland Soil Background Comparison Level*	HBN	RBC Industri; Soil
TAL Inorganics (μg/g)						
Aluminum	14.1	3	22,700 - 27,200	22,921	230,000	1,000,00C
Arsenic	30	3	[33.5] - [200]	9	0.5	0.038
Barium	1	3	243 - 273	109	1,000	72,000
Cadmium	2	3	LT 0.7 - 14.1	0.70	40	510
Calcium	100	3	11,000 - 58,100	109,994	NSA	NA
Chromium	4	3	93.9 - 232	47.46	400	1,000,000*
Cobalt	3	3	[13.5] - [14.6]	27.90	0.8	NA
Copper	7	3	475 - 1,130	29.69	2,900	38,000
Iron	1,000	3	27,600 - 35,900	39,707	NSA	NA
Lead	2	3	[542] - [1,370]	282.84	200	NA
Magnesium	50	3	16,600 - 26,800	45,931	NSA	NA
Manganese	0.275	3	253 - 427	978	8,000	5,100
Mercury	0.1	3	0.206 - 1.69	0.05	20	310
Nickel	3	3	38.2 - 56.1	37.23	1,000	20,000***
Potassium	37.5	3	1,730 - 2,920	3,864	NSA	NA
Silver	4	3	1.92 - 6.31	1.75	200	5,100
Sodium	150	3	704 B - 1,400 B	313.20	NSA	NA
Vanadium	0.775	3	49.1 - 65.2	73.89	560	7,200
Zinc	30.2	3	1,510 - 4,230	373.56	16,000	310,000
Explosives (μg/g)						
24DNT	0.424	3	[1.04] - [56]	NT	1	2,000
TCLP Metals (μg/L)						
Arsenic	10	1	97	NT	5,000	NA
Barium	20	1	1,520	NT	100,000	NA
Chromium	10	1	102	NT	5,000	NA
Silver	2	1	13.2	NT	5,000	NA

* Upland soil samples were collected from 5 locations at RAAP. The mean and standard deviations were calculated. Background comparison levels wen selected from the upper 95 percent confidence interval of the background data set, which is equal to the mean plus two standard deviations.
** Chromium III and compounds.
*** Nickel (soluble salts).
B Analyte was detected in corresponding method blank; values are flagged if the sample concentration is less than 10 times the method blank concentratio for common laboratory constituents and 5 times for all other constituents.
HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumption consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
LT Concentration is reported as less than the certified reporting limit.
NA Not available, no RBC provided.
NSA No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
NT Not tested.
PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given anaytical method.
RBC Risk-based concentration provided by USEPA (USEPA, 1994).
TAL Target analyte list.
TCLP Toxicity Characteristic Leaching Procedure.
μg/g Micrograms per gram.
μg/L Micrograms per liter.
[ ] Brackets indicate that the detected concentration exceeds the HBN and/or RBC.

From Dames & Moore, 1992a

health-based numbers (HBNs) taken from the RCRA permit (USEPA, 1989a). Risk-based concentrations (RBCs) for commercial industrial soils are also presented in Tables 7.1 and 7.3 (soils and sediments, respectively), and RBCs for tapwater are presented in Table 7.2 (USEPA, 1994). Additionally, comparison levels of upland soil background data, as calculated by Dames & Moore (1992a), are included in Table 7.1 (soil) and Table 7.3 (sediment). A total of 10 background soil samples were collected during the RFI from off-post locations in the immediate vicinity of RAAP. Sample locations from the Dames & Moore investigation are shown in Figure 7.1.

7.2.1 SWMU 17A

7.2.1.1. The ash from the Stage and Burn Area was sampled in 1980. The extract procedure (EP) toxicity test determined that the ash was nonhazardous (USAEHA, 1980).

7.2.1.2. Near-surface soil samples (0 to 0.5 feet) were collected from two locations (17ASS1 and 17ASS2) at SWMU 17A to determine if soils had been contaminated by burning activities. No deeper soil samples were collected. All soil samples were analyzed for metals and explosives. Concentrations of arsenic, beryllium, cobalt, copper, lead, and thallium exceeded the HBN or RBC criteria in one or more samples. In sample 17ASS1, concentrations of 15 metals exceeded background comparison criteria for upland soil, but only four of these metals (arsenic, copper, lead, and thallium) also exceeded HBNs, and only arsenic also exceeded the RBC. Cobalt also exceeded the HBN, but did not exceed the background criterion. Four metals exceeded the background comparison criteria in sample 17ASS2, but only arsenic also exceeded the HBN, and only arsenic and beryllium exceeded the RBC. Lead, cobalt, and beryllium also exceeded the HBN, but not background criteria. Based on the data for these two soil samples, arsenic, beryllium, copper, lead, and thallium were identified as potential contaminants of concern in SWMU 17A soils. Concentrations of aluminum, antimony, barium, cadmium, chromium, iron, mercury, nickel, silver, sodium, and zinc in soil sample 17ASS1 exceeded the background criteria but were less than HBNs and RBCs and were not identified as a concern. Samples 17ASS2 also had concentrations of barium, copper, and sodium above background but below HBNs and RBCs. One explosive, 2,4-DNT, was detected in one soil sample (17ASS1). The 2,4-DNT concentration, however, was slightly less than the HBN criterion and much less than the RBC.

7.2.1.3. One sample (17ASW1) also was collected from the surface water ponded in the depression located in the southern end of SWMU 17A to assess the potential for contaminant migration by surface water runoff or infiltration. The surface water sample contained 15 metals at detectable concentrations with three of these exceeding HBN or RBC criteria. Arsenic, chromium and lead exceeded the HBNs by factors ranging from two to three, and arsenic exceeded the RBC by three orders of magnitude. The explosive 2,4-DNT was detected in this surface water sample at a concentration slightly less than 10 times the HBN and three orders of magnitude less than the RBC.

7.2.2 SWMU 17B

7.2.2.1. At the ACD Staging Area (SWMU 17B), one sediment sample (17BSE1) was collected from the concrete-lined settling basin for metals and explosives analysis to determine if runoff from the staging bays could transport contaminants. Arsenic, cobalt and lead concentrations exceeded the HBN criteria, but only arsenic exceeded the RBCs. Concentrations of lead and arsenic were five to 20 times greater than the soil background criteria. Nine other metals (barium, cadmium, chromium, copper, mercury, nickel, silver, sodium, and zinc), although at levels less than the HBNs and RBCs, were detected at concentrations greater than the background soil criteria for upland soils. A relatively high concentration of the explosive 2,4-DNT in this sample exceeded the HBN; however, the concentration was less than the RBC.

7.2.3 SWMU 17C

7.2.3.1. In February 1990, a sample of ash was collected from the ACD (SWMU 17C) and analyzed for EP toxicity (now the toxic characteristic leaching procedure [TCLP]) (USAEHA, 1980). The cadmium concentration (2.42 mg/L) exceeded the Virginia regulatory level of 1.0 mg/L.

7.2.3.2. To address the potential for soil contamination resulting from accumulating burned scrap metal and potentially contaminated ash at SWMU 17C, a total of four soil samples were collected from two locations (17CSS1 and 17CSS2), two surface and two near-surface, and analyzed for metals and explosives. Concentrations of arsenic, beryllium, and cobalt exceeded the HBN criteria in all samples, and arsenic and beryllium exceeded the RBCs. Concentrations of barium in one sample and thallium in three of four samples also exceeded the HBN criteria but did not exceed RBCs. Only barium, beryllium and thallium were detected above both HBN and background comparison criteria. Barium was detected above the HBN only in one sample. Beryllium was detected at less than twice the background criteria. Several other metals (aluminum, chromium, copper, iron, magnesium, mercury, nickel, potassium, silver, sodium, and zinc) were reported at concentrations greater than the upland soil background criteria but were less than the HBN or RBC. Most of the elevated metal concentrations were reported for the two samples collected from 17CSS2, which was located at the southern end of the site. One explosive compound was detected in the 1-foot sample collected at 17CSS2. However, the concentration of the explosive 2,4-DNT did not exceed the HBN or RBC criteria.

7.2.4 SWMU 17D

7.2.4.1 Two surface soil samples (17DSS1 and 17DSS2) were collected at the ACD Ash Staging Area (SWMU 17D) and analyzed for metals and explosives to assess potential soil contamination from the storage of ACD ash and from the coal bottom ash pile. The results of the chemical analyses indicated that concentrations of five metals exceeded the HBN criteria and as many as 11 other metal concentrations were elevated above background soil criteria. Only arsenic exceeded the RBC. In both samples collected, arsenic, cobalt, lead and thallium concentrations exceeded the HBN criteria and arsenic exceeded the RBC in both samples. With the exception of cobalt, the concentrations of these metals also exceeded the soil background criteria by factors ranging from 6 to greater than 10. Although elevated in both samples, copper exceeded the HBN criterion in only one sample (17DSS1). Concentrations of antimony, barium, cadmium, calcium, chromium, iron, mercury, nickel, silver, sodium, and zinc, although less than the applicable HBN or RBC, were greater than the soil background criteria. Explosives were not detected in either sample.

7.2.5 SWMU 17E

7.2.5.1. To determine whether contaminants were migrating from SWMUs 17B, 17C, and 17D to the Runoff Drainage Basin (17E) via surface water runoff, one surface water sample (17ESW1) and one sediment sample (17ESE1) were collected from the basin for metals and explosives analysis. Arsenic, chromium, lead, and 2,4-DNT concentrations exceeded HBNs in the surface water sample from SWMU 17E. However, only arsenic exceed the RBC. Concentrations of 10 additional metals in the sediment sample were greater than the soil background criteria but were less than applicable HBNs or RBCs. In the

SWMU 17E sediment sample, arsenic exceeded the RBC and lead concentrations exceeded the HBN but not the RBC. Cobalt was detected above the HBN criteria but less than the background criterion.

7.2.6 SWMU 40

7.2.6.1. Two wells were installed into the bedrock (40MW2 and 40MW4); however, no water was measured in these wells in October 1991 or March 1992, and they could not be sampled. No soil samples were collected and no soil or aqueous analytical results were obtained during the VI at SWMU 40.

7.3 SUMMARY OF RFI FIELD ACTIVITIES

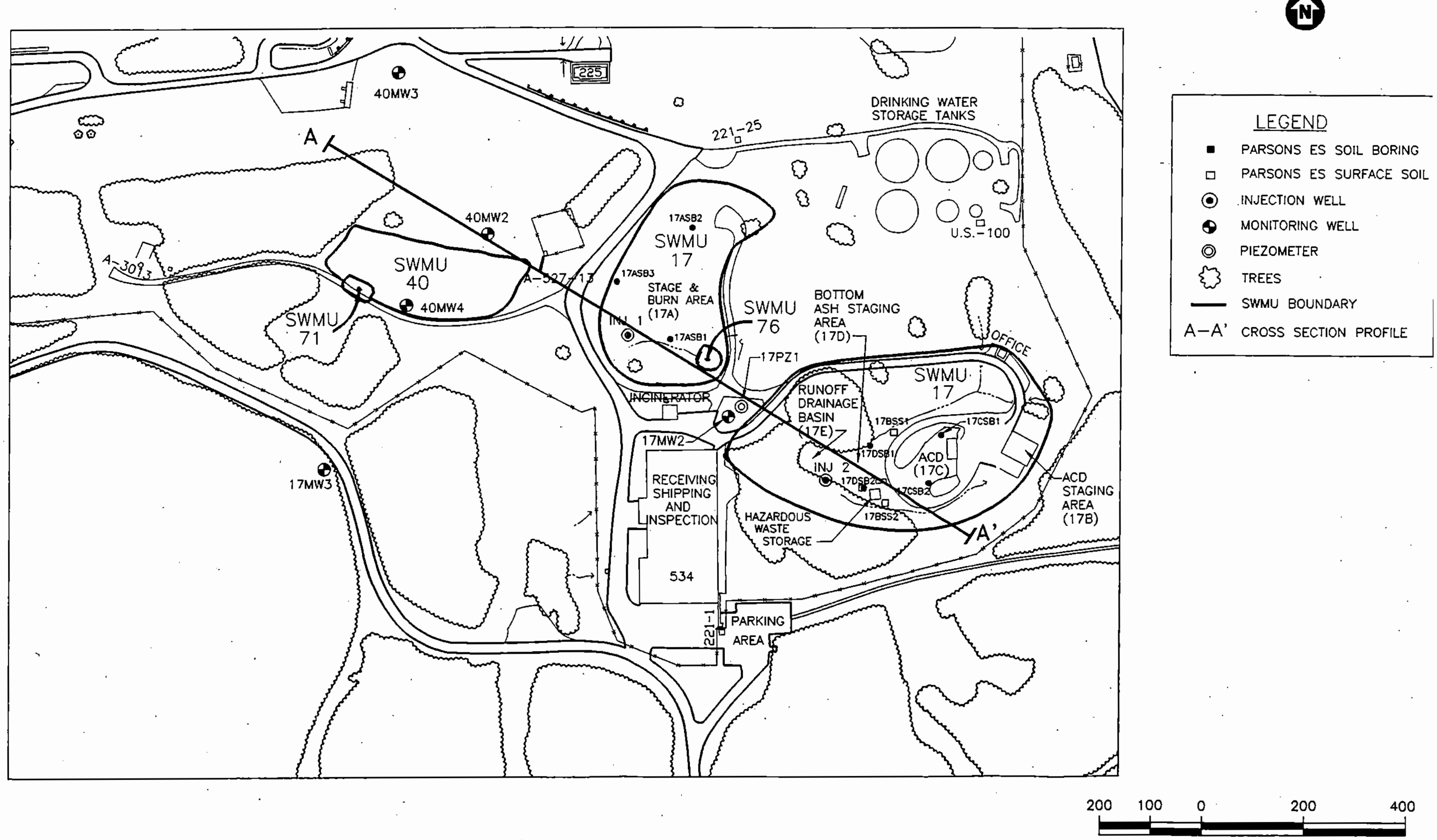
7.3.0.1. The field activities for SWMU 17/40 were not limited to the investigations performed at the sub-areas discussed above, but included the dye tracing test, the sampling of the discharge point determined by the test, and the sampling of the wells installed for monitoring the test. The dye tracing test was completed prior to the Parsons ES RFI field activities, and has been described in detail in Subsection 4.5. The discussion of the sampling of the discharge point and the dye tracing monitoring wells is presented below in the SWMU 17 (Vicinity) subsection. SWMU 17E was not investigated further since it has been adequately characterized. The analytical parameters for the sampling described below are shown in Tables 4.3 and 4.4; the sample locations are shown in Figure 7.2.

7.3.1 SWMU 17A

7.3.1.1. A total of three soil borings were advanced to the soil-bedrock interface at SWMU 17A to better characterize the extent of contamination in SWMU 17A soils. Two borings (17ASB1, 17ASB2) were located near previous RFI soil sampling locations to define the vertical extent of soil contamination and the third boring (17ASB3) was located in the western portion of SWMU 17A to extend soil data coverage both horizontally and vertically.

7.3.1.2. Soil samples were collected at 5-foot intervals from each boring location and submitted for metals and explosives analysis; samples from 5 feet below ground surface and just above the bedrock surface were also analyzed for volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) to address potential soil contamination

FIGURE 7.2
SWMU 17/SWMU 40 SAMPLE LOCATION MAP (CONTAMINATED WASTE BURNING AREA)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



F7-1 12/4/95

resulting from the use of fuels to ignite the burn piles. A composite sample from each boring was analyzed for TOC (to evaluate sorptive properties of the soil) and BTU and waste characterization (to evaluate disposal properties). A near-surface soil sample (0 to 0.5 feet) was collected at 17ASB3 and analyzed for metals and explosives.

7.3.2 SWMU 17B

7.3.2.1. Two channel soil samples were collected from the unlined drainage ditch located adjacent to SWMU 17B. This ditch was previously used to carry runoff from SWMU 17B to SWMU 17E. These soil samples were analyzed for metals and explosives.

7.3.3 SWMU 17C

7.3.3.1. Two soil borings (17CSB1 and 17CSB2) were advanced to the soil-bedrock interface at SWMU 17C near previous RFI soil sampling locations to better characterize the vertical extent of metals and explosives contamination in the soils. Soil samples were collected at 5-foot intervals in each boring and submitted for metals and explosives analysis. A composite sample from each boring was analyzed for TOC, BTU, and waste characterization to evaluate remedial options for the soils.

7.3.4 SWMU 17D

7.3.4.1. Two soil borings (17DSB1 and 17DSB2) were advanced to the soil-bedrock interface in the ACD Ash Staging Area near previous RFI soil sampling locations to better characterize the vertical extent of metals and explosives contamination in the soils. Soil samples were collected at 5-foot intervals in each boring and submitted for metals and explosives analysis. A composite sample was collected from each boring and analyzed for TOC, BTU, and waste characterization to help evaluate remedial options for the soils.

7.3.5 SWMU 17 (Vicinity)

7.3.5.1. Groundwater samples were collected from four of the six monitoring wells in the vicinity of SWMU 17/40. Wells 40MW2 and 40MW4, which were installed around the SWMU 40 landfill during the VI, were dry and could not be sampled. Wells 17PZ1, 17MW2, 17MW3, and 40MW3 were sampled for metals (total and dissolved), explosives, TOC, and TOX. These wells had not previously been sampled (17PZ1 had previously been dry, and the other three were installed to monitor the dye tracing test). Field measurements of the groundwater from these wells were also obtained.

7.3.5.2. The results of the dye tracing test revealed that a spring near the New River was hydraulically connected to SWMU 17. Dye introduced into injection well 1 (located in the 17A sinkhole. The spring, which discharges directly to the New River, is approximately 4,800 feet west of the SWMU 17A sinkhole. Figure 3.10 shows the orientation of the spring, river, and SWMU, as well as fracture traces and other sinkholes in the vicinity. The spring surface water and sediment was sampled (SPG3SW1 and SPG3SE1, respectively) for total metals, explosives, TOC, and TOX. Field measurements were also taken.

7.3.5.3. Table 7.4 summarizes the field activities conducted at SWMU 17/40 for this investigation.

7.4 ENVIRONMENTAL SETTING

7.4.1 Topography and Site Layout

7.4.1.1. SWMU 17 comprises two large sinkholes which dominate the area, and the surrounding buildings which support the burning operations. The westernmost sinkhole is approximately 30 feet deep by 200 feet wide by 400 feet long. SWMU 17A is situated on the level floor of this sinkhole. SWMU 76 is located on the eastern embankment of the sinkhole. A single dirt road leads down to the burning area. The southern part of the sinkhole collects surface runoff water and is often ponded.

7.4.1.2. The other major sinkhole is to the east and south of the 17A sinkhole. The two sinkholes are separated by approximately 100 feet of level ground 30-40 feet above the sinkhole floors. Wells 17PZ1 and 17MW2 are located on this high ground. This sinkhole is approximately 40 feet deep by 600 feet long by 350 feet wide. It also has a single dirt road leading to the level floor.

7.4.1.3. SWMUs 17B, 17C, 17D, and 17E are located in this eastern sinkhole. 17B and 17C are constructed on a level grade slightly above the sinkhole floor. The western section of the sinkhole collects surface water runoff and is often ponded.

SUMMARY OF SWMU 17/40 RFI FIELD ACTIVITIES
RADFORD ARMY AMMUNITION PLANT

Monitoring Wells Sampled*	Surface Water* and Sediment Samples	Soil Boring Samples			Surface Soil Samples
		SWMU Location	Name	Depth (Feet Below Ground Surface)	
17PZ1	SPG3SW1	17A	17ASB105	3-5	17BSS1
17MW2	SPG3SE1		17ASB110	8-10	17BSS2
17MW3			17ASB115	13-15	
40MW3			17ASB120	18-20	
			17ASB122	20-22	
			17ASB1	Composite	
			17ASB205	3-5	
			17ASB210	8-10	
			17ASB215	13-15	
			17ASB220	18-20	
			17ASB225	23-25	
			17ASB2	Composite	
			17ASS3	0-0.5	
			17ASB305	3-5	
			17ASB310	8-10	
			17ASB315	13-15	
			17ASB320	18-20	
			17ASB325	23-25	
			17ASB3	Composite	
		17C	17CSB105	3-5	
			17CSB110	8-10	
			17CSB114	12-14	
			17CSB1	Composite	
			17CSB205	3-5	
			17CSB210	8-10	
			17CSB215	13-15	
			17CSB2	Composite	
		17D	17DSB105	3-5	
			17DSB110	8-10	
			17DSB115	13-15	
			17DSB120	18-20	
			17DSB125	23-25	
			17DSB127	25-27	
			17DSB1	Composite	
			17DSB205	3-5	
			17DSB210	8-10	
			17DSB215	13-15	
			17DSB220	18-20	
			17DSB225	23-25	
			17DSB2	Composite	

* Field measurements of pH, temperature, and conductivity were also collected.

7.4.1.4. The SWMU 40 landfill is approximately 150 feet west of the 17A sinkhole. The highest point of the landfill is approximately equivalent to the divide between the two large sinkholes. SWMU 40 is an area of gently to steeply sloping ridges. To the north, the elevation decreases by approximately 20 feet at the lower boundary of SWMU 40. The SWMU is bordered by trees to the west and south. Numerous paved roads and man-made structures are in the general vicinity of the SWMU 17/40 area.

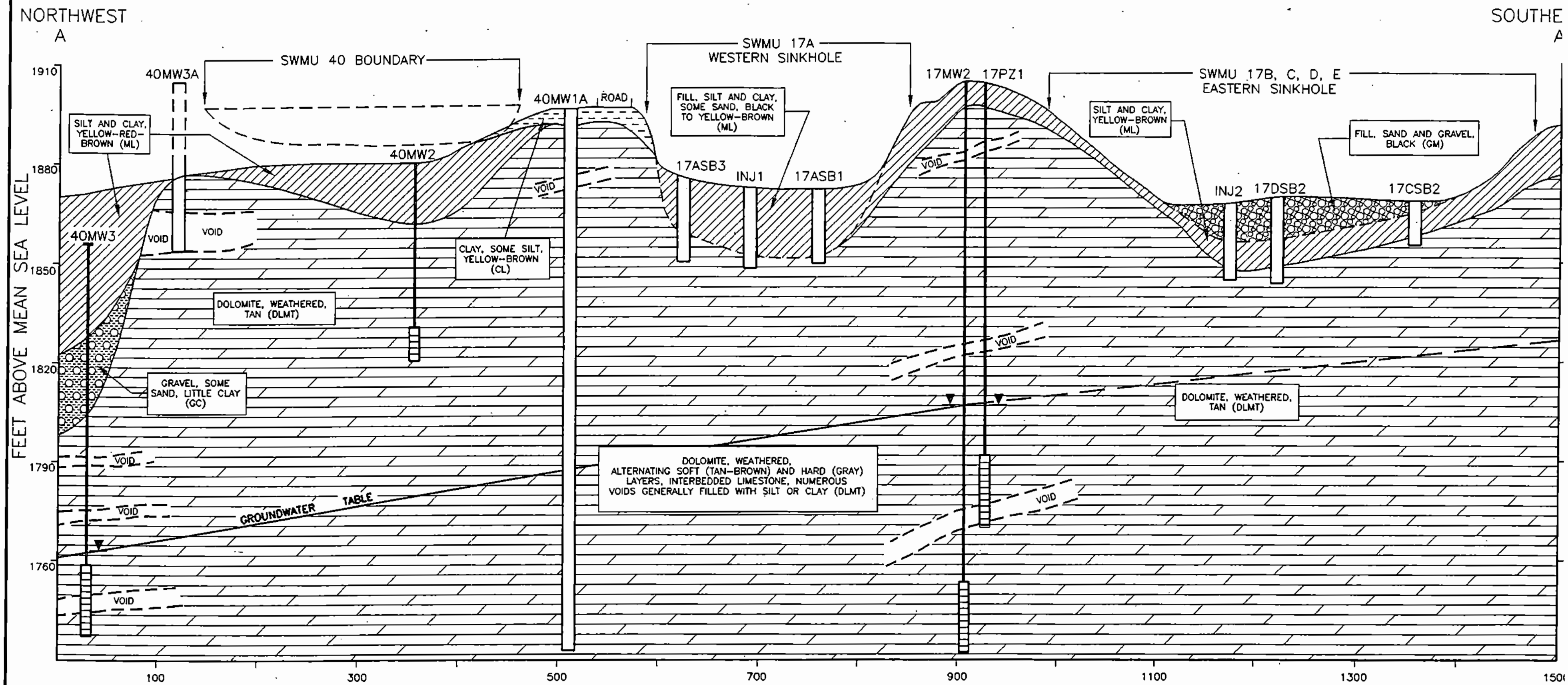
7.4.2 Geology

7.4.2.1. The geology of the SWMU 17 and SWMU 40 area was mostly characterized through previous investigations. Dames & Moore RFI (SWMU 17) and VI (SWMU 40) activities included the installation of three monitoring wells and two soil borings. The Parsons ES dye tracing study investigatory activities included the installation of three monitoring wells and two dye injection wells. Seven additional soil borings were installed for this RFI in the two SWMU 17 sinkholes. The vertical extent of all drilling activities was approximately 190 feet ranging from 1905 feet above mean sea level (amsl) to 1715 feet amsl.

7.4.2.2. All geological samples were categorized under the Unified Soil Classification System (USCS) in accordance with the work plan. The USCS designation was determined in the field by the project geologist. The information from all the investigations was compiled to prepare the geologic cross section presented as Figure 7.3. The profile line, A-A' (Figure 7.2), is a northwest to southeast oriented section which spans both SWMUs and generally parallels the groundwater flow direction as determined by the dye tracing study.

7.4.2.3. As seen in the cross section, very little overburden is present mantling the bedrock in this part of the facility. A thin yellow-brown silt and clay (ML) layer or clay with less silt (CL) layer was generally encountered overlying a weathered dolomite. The overburden thickened in the vicinity of 40MW3 and included a gravel and sand sequence (GC) above the bedrock. It is possible the a filled-in sinkhole is present in this area. The western sinkhole of SWMU 17 contained approximately 20 feet of fill overlying the bedrock. The fill is the probable result of overburden slumping into the sinkhole caused by the collapsed bedrock. The fill was predominantly black to yellow-brown silt and clay, with some sand and gravel; it was penetrated by three soil borings and one injection well. The

FIGURE 7.3
SWMU 17/SWMU 40 GEOLOGIC CROSS SECTION (A-A')
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



LEGEND

HORIZ. SCALE: 1" = 100' (0 – 100)

VERT. SCALE: 1" = 30' (0 – 30)

WELL SCREEN INTERVAL

▼ STATIC GROUNDWATER LEVEL

INJ = INJECTION WELL

NOTES:
1) CROSS SECTION PROFILE A-A' LOCATED ON FIGURE 7.2
2) WATER LEVELS MEASURED JULY 1995.
3) SOME DATA POINTS ARE PROJECTED ONTO PROFILE.
4) 40MW1A, 2, 3A, AND 17PZ1 LITHOLOGY FROM DAMES AND MOOF
5) 40MW1A AND 3A ARE BORINGS.
6) 40MW2 IS HISTORICALLY DRY.
7) INJECTION WELLS ARE OPEN HOLES AT THE BEDROCK INTERFACE
8) LITHOLOGY PATTERNS DO NOT MATCH DRILL LOG PATTERNS DUE TO DIFFERING GRAPHICS SYSTEMS.

J:\CADD\722843\843FG7_3 12/4/95

PARSONS ENGINEERING SCIENCE INC

eastern sinkhole of SWMU 17 contained less fill. Approximately 5-10 feet of black sand and gravel was present above a yellow-brown silt and clay (ML) layer. The ML layer did not appear to be fill; it overlaid the weathered dolomite from 10-20 feet below ground surface (bgs).

7.4.2.4. The Elbrook Formation bedrock underlying the entire SWMU vicinity was predominantly an argillaceous dolomite interbedded with limestone and siltstone. It was very weathered with alternating hard and soft layers; the softer layers were typically tan-brown and the harder layers were gray. Numerous fractures were observed in the cored samples (Dames & Moore); the fractures were usually clay-filled. A substantial number of voids, a typical solution feature, was encountered resulting in losses of drilling fluids and air circulation. In some cases, the voids were partially filled with sand, silt, or clay. The cross section indicates voids where fluid circulation was lost or where coring revealed large filled-in fractures. Some calcite mineralization of the fractures was observed in the core samples. A field test of hydrochloric acid effervescence was conducted to differentiate between limestone and dolomite.

7.4.3 Hydrogeology

7.4.3.1. Currently, there are five monitoring wells, one piezometer and two injection wells within, or in the vicinity of, SWMU 17/SWMU 40 (Figure 7.1). 40MW2 and 40MW4 were installed during VI activities at SWMU 40 (Dames & Moore, 1992a). Both wells were set at approximately 60 feet below ground surface (bgs) and both have been dry since installation. The piezometer at SWMU 17 (17PZ1) was installed during previous RFI activities (Dames & Moore, 1992b) at a depth of 132.5 feet bgs. A 20 foot screen was set at the bottom of 17PZ1, from 112.5 feet to 132.5 feet bgs. In May 1993, three bedrock monitoring wells and two dye-injection wells were installed in the vicinity of SWMU 17 and 40 as part of the dye tracing study conducted at the site (Engineering Science, 1994b). The monitoring wells were designed to intercept the regional water table associated with the New River. Monitoring well 17MW2 is located adjacent to 17PZ1 and is screened between 150 feet and 170 feet bgs. Monitoring well 40MW3 is located in an apparent downgradient flow direction from SWMU 17 and SWMU 40 and is screened at depth between 97 feet and 117 feet bgs. Well 17MW3 was installed along an axis of sinkhole alignment in the area to evaluate the influence of structural features and/or solution features on groundwater flow. The well was completed to a depth of 179 feet and is constructed with 20 feet of screen. The two dye-injection wells (INJ1 and INJ2) are located in the sinkholes comprising SWMUs 17A through 17E. These wells were installed to a maximum depth of 23.5 feet through the fill-overburden to the bedrock interface. Well construction details for the SWMU 17 and SWMU 40 monitoring wells are given in Table 4.1.

7.4.3.2. Groundwater occurrence and movement in the vicinity of these SWMUs is complex. Observations and measurements of the groundwater are consistent with karst subsurface features. As indicated in Section 3.6, although the concept of a groundwater table in karst geology may be misleading, the following discussion is presented to support observations of flow direction and flow rates. The concept of a regional groundwater table in karst geology is applicable when considering the area involved in the direct discharge of SWMU 17 groundwater to the New River (approximately 4,800 feet away) as shown in the dye tracing study.

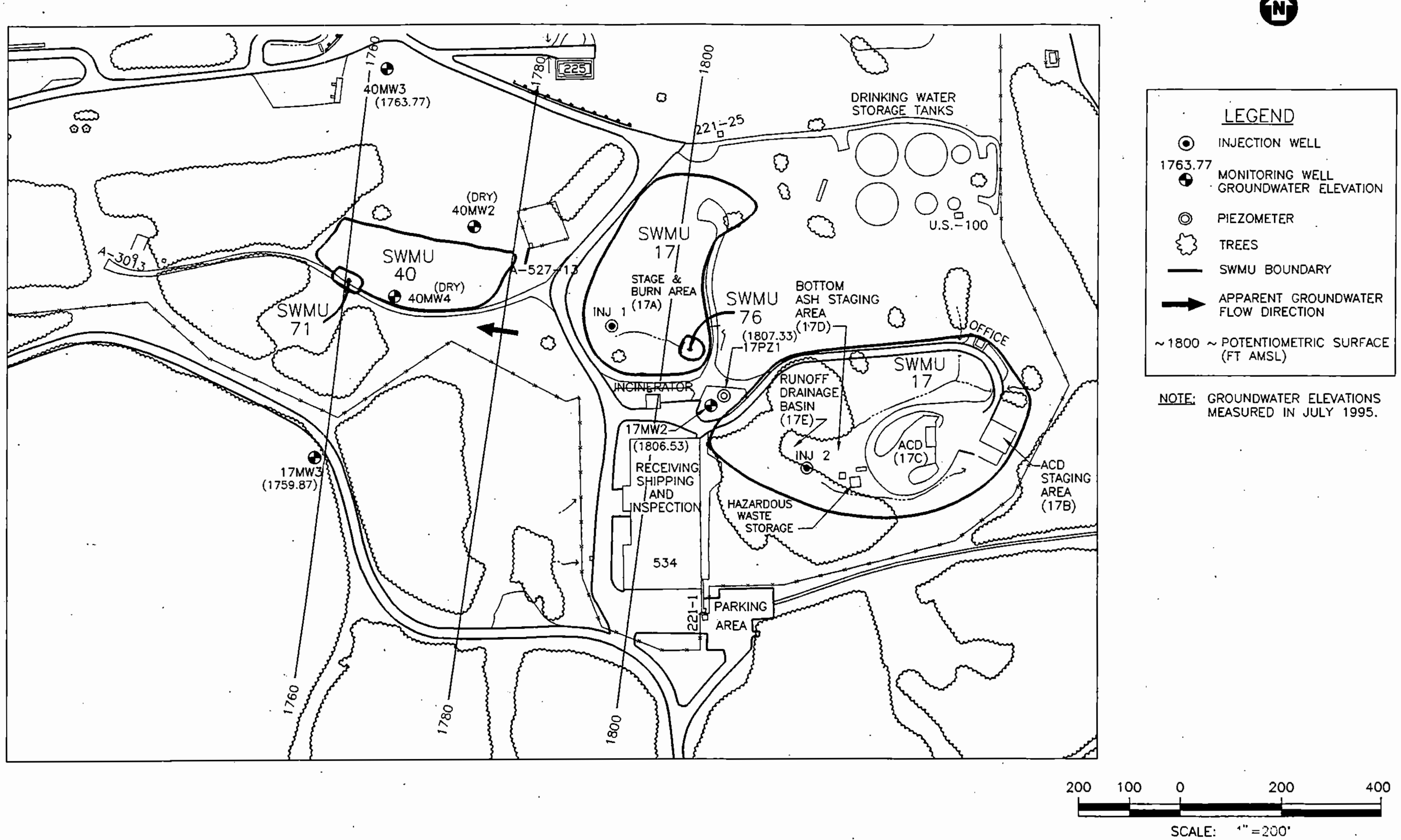
7.4.3.3. The potentiometric surface (groundwater table) at SWMU 17/SWMU 40 is shown in cross section in Figure 7.3 and in plan view in Figure 7.4. Field data used to prepare Figure 7.4, photoionization detector (PID) readings of the well headspace in parts per million (ppm), pH, temperature, and conductivity of the groundwater, are summarized in Table 7.5.

7.4.3.4. The groundwater table in the vicinity of SWMU 17/SWMU 40 is relatively deep (typically greater than 100 feet bgs) and contained within the bedrock of the Elbrook Formation. Groundwater level measurements taken at SWMU 17/SWMU 40 periodically between 1992 and 1995 have demonstrated that the groundwater elevations in this area fluctuate over a wide range. This is especially apparent in 17PZ1 and 17MW2, which has been observed to display 20 to 30 feet of seasonal variation of groundwater levels (approximately five feet of variation was seen in the January and July, 1995 investigations). The observed groundwater fluctuations are typical of groundwater flow through fractures, bedding planes, and karst solution features. The voids encountered in the bedrock during drilling activities of SWMU 17/SWMU 40 (Figure 7.3) have the potential to control or affect groundwater flow rate and direction.

7.4.3.5. The presence of the large sinkholes indicates that SWMU 17 is within a groundwater recharge zone. Figure 7.4 depicts the direction of groundwater flow at

FIGURE 7.4
SWMU 17/SWMU 40 GROUNDWATER POTENTIOMETRIC SURFACE MAP

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



2843F7.1 12/

PARSONS ENGINEERING SCIENCE, INC.

TABLE 7.5
SWMU 17: GROUNDWATER FIELD DATA
RADFORD ARMY AMMUNITION PLANT

Well Name	Date	Depth to Bottom (ft)	Depth to Water (ft)	Groundwater Elevation*(ft)	PID (ppm)	pH	Temperature (degrees F)	Conductivity (us/cm)
17MW2	1-17-95	173.0	106.94	1799.35	6.4	7.19	48.4	0.92
17PZ1	1-17-95	132.5	106.88	1800.14	9.2	7.23	50.2	0.94
17MW3	1-17-95	190.0	146.19	1760.59	3.5	7.08	58.1	0.97
40MW3	1-17-95	120.0	94.38	1763.83	2.9	7.51	58.5	0.94
40MW2	1-17-95	60.0	DRY	NA	NA	NA	NA	NA
40MW4	1-17-95	62.8	DRY	NA	NA	NA	NA	NA
17MW2	7-19-95	173.0	99.76	1806.53	0.0	6.96	76.5	615
17PZ1	7-19-95	132.5	99.69	1807.33	0.0	7.06	78.5	682
17MW3	7-22-95	190.0	146.91	1759.87	0.0	7.12	69.2	298
40MW3	7-21-95	120.0	94.44	1763.77	0.0	7.59	73.6	374
40MW2	7-19-95	60.0	DRY	NA	NA	NA	NA	NA
40MW4	7-19-95	62.8	DRY	NA	NA	NA	NA	NA

* Feet above mean sea level

SWMU17/SWMU 40 toward the west-northwest at a hydraulic gradient of 0.05 feet/foot (ft/ft). The dye tracing study also indicated that groundwater flow in the vicinity of SWMU 17 is toward the west-northwest (Parsons Engineering Science, 1994). The dye tracing study further indicated that a spring (SPG 3) which discharges directly to the New River is hydraulically connected to the sinkhole which SWMU 17A occupies. Dye placed into INJ1 traveled 4,800 feet to the spring in approximately 24 hours. The flow path identified by the dye trace closely parallels a west-northwest to east-southeast trending fracture trace which can be extended to connect both the dye injection point and the dye resurgence point (Figure 3.10). This condition suggests that a direct conduit exists between SWMU 17A and SPG 3 which was likely created by solution opening along a subsurface fracture. The travel time for groundwater flow through this conduit, under low flow conditions, is calculated to range between 2,095 feet/day and 3,716 feet/day and under high flow conditions is calculated to average about 4,800 feet/day. Because dye was not found in any of the monitoring wells, the flow path is interpreted to be narrow and laterally limited.

7.4.3.6 Dye placement into the eastern sinkhole (INJ2) did not infiltrate the subsurface. This may be explained by the presence of the clay rich, non-fill ML layer encountered above the bedrock. It may also indicate a less fractured section of bedrock below the sinkhole.

7.4.4 Surface Water

SWMU 17/SWMU 40 is located in the south-central section of the Main Manufacturing Area in a region of gently to steeply sloping ridges and scattered sinkholes. Based on topography, surface water runoff in this vicinity generally flows northwest approximately 4,800 feet to the New River. However, the sinkholes which comprise SWMU 17A and SWMUs 17B through 17E capture a significant quantity of surface water runoff. Both of these sinkholes contain minor intermittent ponded surface water bodies which act as local recharge areas. The SWMU 17A sinkhole contains a surface water drainage ditch and a small water-filled depression approximately 20 feet across. The SWMU 17B through 17E sinkhole contains two surface water drainage ditches and a swampy runoff drainage basin.

7.5 NATURE AND EXTENT OF CONTAMINATION

7.5.0.1. For the purposes of the nature and extent discussions which follow, the SWMU areas have been grouped by their locations; SWMU 17A is assessed separately from the other SWMU areas, which are grouped together (SWMU 17B,C,D). The SWMU vicinity discussion addresses the monitoring wells. The spring location (SPG3) which has been shown to be hydraulically connected to the SWMU 17A sinkhole had been part of the SWMU vicinity discussions. However, for a more detailed contamination evaluation, that sample has been included with the New River section (Section 12), since the results are likely to reflect the river environment as well as the SWMU 17A environment.

7.5.0.2. All positive results (detected compounds) for soil samples for SWMU 17A and SWMU 17B,C,D are presented in Tables 7.6 and 7.7, respectively. The positive results for the aqueous samples for SWMU 17/40 (vicinity) are presented in Table 7.8. The chemicals of concern (COCs) were identified by the methods described in Section 6. The focus of this section is on the COCs determined to be potential human health threats as discussed in the subsequent Risk Assessment subsections.

7.5.1 Nature of Contamination (SWMU 17A)

7.5.1.1 Surface Soils

7.5.1.1.1 Only one surface soil sample was collected at 17A. This sample, 17ASS3, was the surface portion of the 17SB3 boring. However, other data from the previous Dames & Moore investigation were also considered for 17A surface soils. Metals detected at COC levels included: arsenic, lead, silver, barium, beryllium, cadmium, chromium, nickel, and mercury. Of these, arsenic and beryllium were found at levels considered to pose a potential threat to human health. Therefore, arsenic and beryllium were determined to be the risk drivers. The concentrations of all of the metals with positive results, except beryllium, exceeded Dames & Moores's background levels for upland soils.

7.5.1.1.2 The arsenic concentration was 101.70 ug/g. Lead was found at 4721.55 ug/g. Cadmium and nickel were detected at 4.29 ug/g and 69.13 ug/g, respectively. Beryllium, at a concentration of 0.98 ug/g, was less than background in this sample.

TABLE 7.6
POSITIVE RESULTS TABLE OF SWMU 17 - Solid Samples (SWMU 17a)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17ASB105	17ASB110	17ASB115	17ASB120	17ASB122	17ASB205
METALS (ug/g)						
Arsenic	94.87 J4	9.30 J4	13.50 J4	16.69 J4		7.33 J4
Lead	5256.41 J6	101.39 J6	56.44 J6	273.97 J6	11.79 J6	26.28 J6
Silver	42.31 J4	0.39 J4		2.12 J4		
Barium	5128.21 J1	63.12 J1	69.20 J1	69.36 J1	71.50 J1	64.38 J1
Beryllium	1.65 J4	2.22 J4	2.11 J4	1.77 J4	2.13 J4	2.23 J4
Cadmium	13.72					
Chromium	2051.28 J6	55.51 J6	54.72 J6	54.92 J6	68.50 J6	46.82 J6
Nickel	902.56 J4	24.84 J4	29.20 J4	24.28 J4	28.37 J4	26.15 J4
Antimony	77.95					
Mercury	0.29 J4	0.14 J4	0.16 J4	0.11 J4	0.09 J4	0.18 J4
SEMIVOLATILES (ug/g)						
Bis(2-ethylhexyl) phthalate	10.13				2.48	5.85
Benzo[a]anthracene	0.99					
Benzo[b]fluoranthene	1.92					
Benzo[ghi]perylene	1.23				0.24	0.22
Benzo[k]fluoranthene	0.56					
Chrysene	1.04					
Diethyl phthalate						
Fluoranthene	0.81					
Phenanthrene	1.67					
Pyrene	1.54					
OTHER (ug/g)						
Total Organic Carbon						

TABLE 7.6
POSITIVE RESULTS TABLE OF SWMU 17 - Solid Samples (SWMU 17a)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17ASB210	17ASB215	17ASB220	17ASB225	17ASB305	17ASB310
METALS (ug/g)						
Arsenic		8.98 J4			6.70 J4	7.51 J4
Lead	14.13 J6	69.06 J6	41.78 J6	77.36 J6	27.08 J6	23.02 J6
Silver						
Barium	75.69 J1	86.91 J1	134.26 J1	9.56 J1	71.26 J1	126.39 J1
Beryllium	2.06 J4	4.52 J4	6.82 J4		3.40 J4	7.39 J4
Cadmium						
Chromium	49.70 J6	86.04 J6	122.27 J6	7.56 J6	53.71 J6	79.33 J6
Nickel	27.78 J4	56.83 J4	78.96 J4	6.12 J4	34.64 J4	71.26 J4
Antimony						
Mercury		0.12 J4			0.18 J4	0.13 J4
SEMIVOLATILES (ug/g)						
Bis(2-ethylhexyl) phthalate					3.48	
Benzo[a]anthracene						
Benzo[b]fluoranthene						
Benzo[ghi]perylene				0.26	0.27	
Benzo[k]fluoranthene						
Chrysene						
Diethyl phthalate						
Fluoranthene						
Phenanthrene						
Pyrene						
OTHER (ug/g)						
Total Organic Carbon						

TABLE 7.6
POSITIVE RESULTS TABLE OF SWMU 17 - Solid Samples (SWMU 17a)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17ASB315	17ASB320	17ASB325	17ASB340*	17ASS3
METALS (ug/g)					
Arsenic	4.64 J4	3.75 J4		3.30 J4	101.70 J4
Lead	21.83 J6	30.77 J6	9.23 J6	15.70 J6	4721.55 J6
Silver					2.18 J4
Barium	45.16 J1	52.97 J1	54.71 J1	34.58 J1	577.48 J1
Beryllium	2.20 J4	0.57 J4	0.77 J4	1.55 J4	0.98 J4
Cadmium					4.29
Chromium	75.99 J6	17.25 J6	22.59 J6	45.44 J6	222.76 J6
Nickel	36.43 J4	6.30 J4	10.90 J4	23.71 J4	69.13 J4
Antimony					
Mercury					0.33 J4
SEMIVOLATILES (ug/g)					
Bis(2-ethylhexyl) phthalate			2.30		
Benzo[a]anthracene			0.29		
Benzo[b]fluoranthene					
Benzo[ghi]perylene			0.20	0.20	
Benzo[k]fluoranthene					
Chrysene			0.25		
Diethyl phthalate			9.87		
Fluoranthene			0.38		
Phenanthrene			0.65		
Pyrene			0.50		
OTHER (ug/g)					
Total Organic Carbon				10406.10	

* 17ASB340 is a duplicate sample of 17ASB315

TABLE 7.7
POSITIVE RESULTS TABLE SWMU 17 - Solid samples (SWMUs 17b,17c, 17d)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17BSS1	17BSS2	17CSB105	17CSB110	17CSB114	17CSB205	17CSB210
METALS (ug/g)							
Arsenic	127.72 J4	18.18 J4	11.98 J4				
Lead	653.12 J1	128.43 J1	41.82 J1	18.44 J1	18.73 J1	12.20 J1	13.68 J1
Silver	1.89 J4	0.13 J4					
Barium	261.25 J1	99.42 J1	29.40 J1	78.55 J1	84.33 J1	36.74 J1	70.12 J1
Beryllium	1.41 J4	5.61 J4	3.23 J4	5.19 J4	3.61 J4	1.56 J4	5.77 J4
Cadmium	3.12 J4						
Chromium	144.41	76.05	61.87	72.81	59.89	33.62	54.29
Nickel	40.49 J4	51.80 J4	25.95 J4	46.17 J4	35.33 J4	18.68 J4	46.60 J4
Mercury	0.25 J4			0.10 J4			
OTHER (ug/g)							
Total Organic Carbon							

TABLE 7.7

POSITIVE RESULTS TABLE SWMU 17 - Solid samples (SWMUs 17b,17c, 17d)

RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17CSB215	17CSB240*	17DSB105	17DSB110	17DSB115	17DSB120	17DSB125
METALS (ug/g)							
Arsenic	4.59 J4						
Lead	190.60 J1	17.24 J1	20.08 J1	17.95 J1	26.54 J1	12.36 J1	28.23 J1
Silver	0.04 J4		0.03 J4				
Barium	104.70 J1	86.49 J1	68.93 J1	60.40 J1	67.05 J1	69.69 J1	72.73 J1
Beryllium	2.52 J4	6.21 J4	1.83 J4	2.02 J4	3.21 J4	3.04 J4	4.77 J4
Cadmium	4.73 J4						
Chromium	71.92	74.38	29.92	43.94	67.82	56.07	86.92
Nickel	45.62 J4	56.83 J4	14.58 J4	16.21 J4	28.97 J4	45.53 J4	50.40 J4
Mercury							
OTHER (ug/g)							
Total Organic Carbon		1552.79					

* 17CSB240 is a duplicate of 17CSB215

TABLE 7.7
POSITIVE RESULTS TABLE SWMU 17 - Solid samples (SWMUs 17b,17c, 17d)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17DSB127	17DSB205	17DSB210	17DSB215	17DSB220	17DSB225	17DSB240*
METALS (ug/g)							
Arsenic			6.32 J4	11.32 J4			8.03 J4
Lead	23.46 J1	20.81 J1	17.87 J1	23.10 J1	11.31 J1	8.43 J1	14.63 J1
Silver	0.07 J4						
Barium	111.48 J1	65.89 J1	80.98 J1	142.65 J1	111.91 J1	55.95 J1	68.85 J1
Beryllium	5.89 J4	1.42 J4	2.48 J4	7.88 J4	5.48 J4	11.84 J4	2.23 J4
Cadmium							
Chromium	77.87	31.28	56.30	97.09	63.30	77.76	49.18
Nickel	66.39 J4	11.18 J4	28.79 J4	72.05 J4	57.42 J4	87.82 J4	23.33 J4
Mercury	0.15 J4			0.24 J4			
OTHER (ug/g)							
Total Organic Carbon							2723.83

* 17DSB240 is a duplicate of 17DSB215

TABLE 7.8
POSITIVE RESULTS TABLE OF SWMU 17 - Aqueous Samples (SWMU 17 Vicinity)
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	17MW3	17MW3 Dissolved	17MW2	17MW2 Dissolved	17PZ1	17PZ1 Dissolved	40MW3	40MW3 Dissolved
METALS (ug/l)								
Lead	6.3							
Selenium			3.63					
Barium	174	164	63.6	63.2	106	110	54.5	31
Beryllium			4.03	4.26	4.55	4.28		
Antimony			60.2*					
OTHER (ug/l)								
Total Organic Carbon	1240							
Total Organic Halogens	107		27.5		15.7			

* The positive result for antimony was detected during the January 1995 sampling event.
All other results from July 1995.

7.5.1.2 Subsurface Soils

7.5.1.2.1 Positive results for ten metals and ten SVOCs were detected in the SWMU 17A subsurface samples. Of these, the following were considered to be COCs: antimony, arsenic, barium, cadmium, chromium (as chromium III), lead, nickel, silver, benzo(a)anthracene, benzo(b)fluoranthene, bis(2-ethyl hexyl)phthalate, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, fluoranthene, and phenanthrene. The risk drivers were antimony and arsenic.

7.5.1.2.2 Eight metals concentrations were found at levels greater than the established background for soil horizon B (less than five feet bgs). Those metals were: antimony, arsenic, barium, cadmium, chromium, lead, nickel, and silver. Arsenic, lead, and silver exceeded the soil horizon C background levels.

7.5.1.2.3 In general, the arsenic, barium, cadmium, nickel, and lead levels in the 3-5 foot interval from 17ASB1 (B horizon) were significantly higher than in any other samples. The only antimony (risk driver) detection was from this boring (77.95 ug/g). The arsenic level in this sample was 94.87 ug/g; no other arsenic level exceeded 17 ug/g. The lead concentration in 17ASB105 was 5256.41 ug/g; the next highest level was 273.97 ug/g in 17ASB120, which is the same boring (18-20 foot bgs interval). The barium level was 5128.21 ug/g in 17ASB105. The next highest level was 134.26 ug/g in 17ASB220.

7.5.1.2.4. The significant SVOC detections were mostly in the 17ASB105 sample. All of the SVOC COCs were found in this sample. Few SVOCs were found at depth in this boring. Some SVOCs were found in the 17ASB2 boring, but none at depths greater than five feet. The other significant SVOC detections were in the 17ASB3 boring, from the 23-25 foot bgs interval. The SVOCs were mainly polynuclear aromatic hydrocarbon (PAH) compounds.

7.5.2 Nature of Contamination (SWMU 17B,C,D)

7.5.2.1 Surface Soils

7.5.2.1.1. Two surface soil samples were collected at SWMU 17B,C,D. Positive results for nine metals were found in these surface samples. The nine metals, which were all

COCs, were: arsenic, lead, silver, barium, beryllium, cadmium, chromium nickel, and mercury. Arsenic and beryllium were found at concentrations considered to be a potential human health threat. Therefore, these metals were categorized as risk drivers for SWMU 17B,C,D surface soils.

7.5.2.1.2. The concentrations of the risk drivers exceeded the Dames & Moore background levels established for upland soils for these metals. Both 17BSS1 and 17BSS2 contained arsenic and beryllium detections. The maximum level of arsenic (127.72 ug/g) was from the 17BSS1 sample. 17BSS2 contained the highest beryllium concentration (5.61 ug/g).

7.5.2.1.3. Cadmium was only found in 17BSS1 (3.12 ug/g). The rest of the positive metals detections were evenly distributed between the two surface samples, although the COC mercury was not found in 17BSS2.

7.5.2.2 Subsurface Soils

7.5.2.2.1. Nine metals had positive results in the subsurface samples taken at SWMU 17B,C,D. They were: arsenic, lead, silver, barium, beryllium, cadmium, chromium, nickel, and mercury. Arsenic and lead were COCs. Only arsenic was found at levels considered to be a human health threat and therefore was categorized as the risk driver for subsurface soils at SWMU 17B,C,D.

7.5.2.2.2. Arsenic was detected in four subsurface soil samples, ranging from 4.59 ug/g in 17CSB215 to 11.98 ug/g in 17CSB105. These concentrations exceeded the background level established for B horizon subsurface soils. The B horizon (less than five feet bgs) background for arsenic, 5.5 ug/g, was exceeded in the 17CSB105 sample. The C horizon background for arsenic (11.5 ug/g) was not exceeded. The other COC, lead, was detected in 17 subsurface samples, ranging from 190.60 ug/g in 17CSB215 to 8.43 ug/g in 17DSB225. However, no B horizon samples exceeded the background lead level of 190.56 ug/g, and only the 17CSB215 sample exceeded the C horizon background lead level of 112.16 ug/g.

7.5.2.2.3. Of the other positive metals results, only cadmium exceeded the background level (3.5 ug/g) for the C horizon. This occurred in the 17CSB215 sample. The other detected metals were distributed evenly throughout the samples taken in the 17B,C,D sinkhole.

7.5.3 Nature of Contamination (Vicinity)

7.5.3.1 Groundwater

7.5.3.1.1. Positive results for five metals (lead, antimony, selenium, barium, and beryllium) were found in the samples from the SWMU 17/40 groundwater. Three of these metals, antimony, barium and beryllium, were identified as COCs. Beryllium and antimony were categorized as the risk drivers for groundwater for SWMU 17/40. Dissolved barium was detected in the samples from all four monitoring wells. Dissolved barium concentrations ranged from 31 ug/l in the sample from 40MW3 to 164 ug/l in the sample from 17MW3. Dissolved beryllium was only found in the 17MW2 (4.26 ug/l) and 17PZ1 (4.28 ug/l) samples. Dissolved antimony was only detected in 17MW2 during the January 1995 sampling event at 60.2 ug/l.

7.5.3.1.2. Lead and selenium were detected as total concentrations and were not found in the dissolved state. Selenium was only detected in one sample (from 17MW2 at 3.63 ug/l). Lead was only detected in one sample (6.3 ug/l in 17MW3).

7.5.4 Extent of Contamination (17A)

7.5.4.1 Surface Soils

7.5.4.1.1. Only one surface soil was collected at SWMU 17A. The location was along the western edge of the sinkhole floor. Concentrations of arsenic, beryllium, and lead, the COCs identified by Dames & Moore for surface soil samples along the northern and southern sinkhole floor edge, were similar to the 17ASS3 results.

7.5.4.2 Subsurface Soils

7.5.4.2.1. The maximum concentrations of the COCs were found in the near surface sample of 17ASB1. This sample is located nearest the active burning operations in the

SWMU 17A sinkhole; the other two borings were installed along the edges of the sinkhole floor. Metals were generally evenly distributed throughout, with the exception of the above sample. 17ASB3 is located west of 17ASB1, in the apparent downgradient groundwater direction. Contaminants at depth found in 17ASB3 may be the result of shallow groundwater movement in the fill above the bedrock.

7.5.4.2.2. Some of the metals found in these subsurface samples were also detected in the groundwater samples. Barium, beryllium, and lead were also found in the surface water and sediment samples from SPG3, the spring which has been shown to be directly connected to SWMU 17A by a subsurface groundwater conduit.

7.5.5 Extent of Contamination (17B,C,D)

7.5.5.1 Surface Soils

7.5.5.1.1. There were only two surface soil samples collected at SWMU 17B,C,D. Both were taken to characterize SWMU 17B, the drainage ditches associated with the ACD Staging Area. 17BSS1 contained all the risk driver metals at levels above the Dames & Moore background concentrations for upland sediments. 17BSS2 contained arsenic at concentrations greater than background. That sample contained no detectable amounts of cadmium.

7.5.5.1.2. The 17BSS1 sample generally exceeded the concentrations found in the 17BSS2 sample for all the COCs except beryllium and nickel. 17BSS1 was collected on the north side of the sinkhole floor area, and 17BSS2 was taken from the south side. The locations are approximately 100 feet apart. Each sample is from a separate surface water drainage ditch; both ditches drain into the SWMU 17E Drainage Basin.

7.5.5.2 Subsurface Soils

7.5.5.2.1. Arsenic only exceeded the established background level for the B horizon in one sample, 17CSB105. This maximum subsurface arsenic concentration (11.98 ug/g) was found at the 3-5 foot bgs interval in the boring, which was located on the north side of SWMU 17C. This sample also contained the second highest lead concentration (41.82 ug/g) and a relatively high chromium concentration (61.87 ug/g), although not above the background level. The southern SWMU 17C boring sample, collected from the 13-15 feet bgs interval, exceeded the background levels of lead and cadmium. This sample also contained the maximum barium concentration, 104.70 ug/g, for subsurface soils.

7.5.5.2.2. No other metals exceeded the established background levels for subsurface soils at SWMU 17B,C,D. Of the other detected metals, concentrations appeared to be relatively evenly distributed. Mercury was found in each of the 17D borings; the maximum barium concentration (142.65 ug/g) was found in the 17DSB215 sample, collected from 13-15 feet bgs.

7.5.6 Extent of Contamination (Vicinity)

7.5.6.1 Groundwater

7.5.6.1.1. Barium and the risk driver beryllium were found at similar levels in the samples from 17MW2 and 17PZ1. These wells are adjacent to one another (between the two sinkholes) and the groundwater would be expected to be of similar quality. Antimony was present, at a level just above the detection limit, in 17MW2 during the January 1995 sampling event. Because of the unpredictable components of groundwater flow through the karst subsurface, these wells could be impacted by contaminants present in either sinkhole.

7.5.6.1.2. 17MW3 can be considered to be hydraulically downgradient of both sinkholes based on the observed dye tracing study flow direction. However, this well is also completed in the karst subsurface and could be impacted by flow from other directions. The sample from this well contained the highest dissolved barium concentration, and the only lead detection. Monitoring well 40MW3, which is located in the downgradient groundwater flow direction as determined by the dye tracing study, only had a positive detection for barium. Although in the general downgradient direction, this well did not have dye detections during the tracing study. This may indicate that a narrow conduit exists between the 17A sinkhole and the New River. It is possible that 40MW3 does not fully intercept the preferential pathway to the river, resulting in little migration of contaminants to this well.

7.5.6.1.3 The 17A sinkhole is directly linked to a spring (SPG3) which discharges to the New River. The SPG3 surface water and sediment sample results, which are discussed in more detail in the New River section of this report, indicate positive results for barium, beryllium, and lead.

7.6 CONTAMINANT FATE AND TRANSPORT

7.6.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. At SWMU 17/40, groundwater is the primary migration pathway.

7.6.0.2. The sinkholes for both SWMU 17 areas consist of fill overlying bedrock. The bedrock contains karst features which make groundwater movement and occurrence unpredictable. The dye tracing study demonstrated a direct connection between the SWMU 17A sinkhole and the New River through a spring on the bank of the river approximately 4,800 feet from the SWMU. The travel time calculated for groundwater flow through this conduit ranged between 2,095 feet/day and 4,800 feet/day.

7.6.0.3. Contaminants found in the surface and subsurface soils have been found in the groundwater in the SWMU 17/40 vicinity, and also in the sediment and surface water of the spring (SPG3). The demonstrated connection between these points may represent a preferential migration pathway through a relatively narrow conduit since a minimum of contaminants were detected in the groundwater sample from 40MW3 (located directly in the downgradient groundwater flow direction). Well 17MW3 did contain detectable contaminants although it appears to be side gradient to groundwater flow. This may indicate other migration pathways which were not necessarily detected in the dye tracing study.

7.6.0.4. Although the majority of the metals should be relatively immobile in the undisturbed soil matrix, the contaminants found in the deeper 17A boring samples may be the result of downward leaching from the fill at shallow depths. Groundwater or surface water infiltration in the 17A fill may have allowed for the migration of shallow contamination at 17SB1 to the deeper intervals of boring 17ASB3.

7.6.0.5. SVOCs were identified in the subsurface soils. SVOCs have a high affinity for organic matter and low water solubility. These compounds tend to remain bound to soil particles and dissolve slowly into groundwater. Therefore, the movement of SVOCs is usually controlled by the transport of particulates. SVOCs are readily bioaccumulated by living organisms. The SPG3 sample was not analyzed for VOCs or SVOCs, so it is not known if these contaminants (some of which were detected in SWMU 17 subsurface soils) migrated through the karst conduit to the river. SVOCs were found in various sediment samples collected from the New River downstream of the discharge point, but these may have other sources. Those samples are discussed in Section 12.

7.7 RISK ASSESSMENT

7.7.0.1. SWMU 17 has been divided into five components, four of which are being analyzed for this risk assessment. For risk assessment purposes, SWMU 17A, the Stage and Burn Area, is being evaluated separately from SWMUs 17B, 17C and 17D, which are being grouped and evaluated together. This is due to the close proximity of SWMUs 17B, 17C and 17D (which are physically separated from SWMU 17A) and the potential contaminant migration pathways involved. SWMU 17A is a below-grade (sinkhole) burning pit that is unlined and open to the atmosphere, which does not limit contaminants migrating from explosives-contaminated ash and fuels to the atmosphere, soils and groundwater.

7.7.0.2. SWMUs 17B, 17C and 17D are located in another sinkhole adjacent to SWMU 17A. SWMU 17B is partially covered and contains a concrete staging pad which collects surface water runoff. Contaminants would be limited migrating to soils and groundwater, but contaminant migration to the atmosphere may still occur from contaminated ash. SWMU 17C is an open, concrete-lined controlled burning area. Again, the only potential contaminant migration pathway is to the atmosphere. SWMU 17D is a metal shed with a concrete floor which is used for ash staging. The migration pathways for this SWMU are effectively limited.

7.7.0.3. SWMU 17 is currently in use and this function is expected to continue while the plant exists. It is unlikely that this plant will close as it is the only remaining propellant and explosive manufacturing facility in the country. Therefore, future land use is assumed to remain industrial.

7.7.1 Summary of Chemicals of Potential Concern

7.7.1.0.1. The chemicals considered in the risk evaluation for groundwater at SWMU 17 include antimony, barium and beryllium. The chemicals of concern for surface soils at SWMU 17A are 8 metals (arsenic, barium, cadmium, chromium III, lead, mercury, nickel and silver). The chemicals of concern for subsurface soils at SWMU 17A include 9 metals (antimony, arsenic, barium, beryllium, cadmium, chromium III, lead, nickel and silver) and 9 semivolatiles (benzo(a)anthracene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, bis(2ethylhexyl)phthalate, chrysene, fluoranthene pyrene, and phenanthrene).

7.7.1.0.2. The chemicals of concern for surface soils at SWMU 17 B,C,D are 9 metals (arsenic, barium, beryllium, cadmium, chromium III, lead, mercury, nickel and silver). The chemicals of concern for subsurface soils at SWMU 17B,C,D are arsenic and lead.

7.7.1.0.3. SWMU 17E functions as a surface water runoff drainage basin which appears to be a natural drainage ditch rather than a constructed system. The sampling protocol did not include sampling the surface waters or sediments associated with this area. In addition, during the July sample event, there was no standing surface water in this drainage system. Therefore, surface water is not included in this evaluation of risk for SWMU 17.

7.7.1.1 Comparison to ARARs and TBCs for Groundwater and Soils

7.7.1.1.1. Groundwater in the vicinity of RAAP is not used for drinking water serving more than 25 people and therefore MCLs and MCLGs are not considered as ARARs for SWMU 17. In addition, there are no Federal or Commonwealth of Virginia standards relating chemical concentrations in soils to toxic effects on vegetation or wildlife. TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995).

7.7.2 Exposure Assessment

7.7.2.1 Potential Pathways and Receptors

7.7.2.1.1. The current exposure pathway at SWMUs 17A and 17 B,C,D which is considered to have a high probability of completion is site worker exposure to surface soils. The current construction worker exposure to surface and subsurface soil scenarios also have a high probability of completion should construction activities occur at this SWMU. Other current exposure pathways are considered to have a low probability of completion and therefore, these scenarios were not quantified for current receptors (area residents and fishermen). This SWMU is still active and site workers have access to potentially contaminated surface soils. SWMUs 17A and 17 B,C,D are completely contained within RAAP property which effectively limits public access (residents and fishermen) to potential contaminants. The current groundwater pathway is not complete as groundwater is not used for drinking purposes.

7.7.2.1.2. The potential future exposure scenario quantified for SWMU 17 was future site worker exposure to groundwater through ingestion and dermal contact. This exposure scenario has a low probability of completion since drinking water at RAAP is obtained from the New River However, evaluation of this exposure scenario allows for quantification of the risks due to groundwater exposure. Evaluation of other future exposure scenarios would not be approporiate based on future land use assumptions.

7.7.2.1.3. The conceptual site model summary for SWMU 17 is presented in Figure 7.5 and includes exposure routes, potential receptors and the medium containing the potential contaminants of concern. All chemicals not eliminated by data validation were considered in the risk assessment for this SWMU.

7.7.2.2 Exposure Point Concentrations and Chronic Daily Intakes

7.7.2.2.1. Exposure point concentrations for the metals detected in SWMU 17 groundwater (see Section 7.7.1) are listed in the tables in Appendix I. These concentrations range from 0.00155 mg/L (beryllium) to 0.0771 mg/L (barium). Exposure point concentrations for the contaminants of concern in surface soils at SWMU 17A (also see Section 7.7.1) range from 0.329 ppm (mercury) to 4,720 ppm (lead). Exposure point

Figure 7.5
Conceptual Site Model for Current and Future Exposure Pathways
SWMU 17 ABCD
Radford Army Ammunition Plant
Radford, Virginia

Primary Source	Release Mechanism	Receiving Medium	Exposure Route	Current Receptors: Site Workers	Current Receptors: Rec. Users	Current Receptors: Hunters, Fisherman	Current Receptors: Const. Workers	Future Receptor: Site Workers
RAAP Activities	Surface Runoff/ Groundwater Discharge	Surface Water and Sediment	Ingestion					
			Inhalation					
			Dermal					
	Tracking Deposition	Surficial Soils	Ingestion	X		X(H)	X	
			Inhalation	X			X	
			Dermal	X		X(H)	X	
	Leaching/ Deposition	Subsurface Soils	Ingestion				X	
			Inhalation				X	
			Dermal				X	
	Uptake	Biota	Ingestion					
	Leaching	Groundwater	Ingestion					X
			Inhalation					
			Dermal					X

X = Pathways of potential concern
H = Hunter scenario

concentrations for contaminants of concern at SMWU 17A subsurface soils range from 0.073 ppm (fluoranthene) to 5,260 ppm (lead).

7.7.2.2.2. Exposure point concentrations for the nine metals evaluated in SWMU 17 B,C,D surface soil range from 0.0941 ppm (mercury) to 290 ppm (lead). Exposure point concentrations for the chemicals of concern in subsurface soils range from 8.13 ppm (arsenic) to 27.4 ppm (lead).

7.7.3 Risk Characterization

7.7.3.0.1. The carcinogenic risk and hazard index were calculated for the groundwater ingestion and dermal contact pathways (future site worker receptor) and surface and subsurface soil ingestion, dermal contact, and inhalation of volatiles and particulates (construction worker, site worker and hunters). These calculations are presented in Appendix I. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

7.7.3.1 Non-carcinogenic Effects

7.7.3.1.1. The calculated hazard index for the hypothetical future site worker groundwater ingestion exposure scenario exceeds acceptable levels due to the presence of antimony. The RME receptor hazard index is 1.01. The dermal contact exposure scenario hazard indices are within acceptable levels. The calculated hazard indices for current site worker surface soil exposure scenarios at SWMUs 17A and 17B,C,D do not exceed acceptable levels.

7.7.3.1.2. The calculated hazard indices for the construction worker surface soil ingestion exposure scenario exceeds acceptable levels for RME receptors at SWMU 17A. At SWMU 17A, the surface soil ingestion hazard index for RME receptors exceeds one primarily due to arsenic (1.59).

7.7.3.1.3. The calculated hazard indices for the construction worker subsurface soil ingestion and dermal contact scenarios exceed acceptable levels for CT and RME receptors at SWMU 17A, with the exception of the CT ingestion scenario. The subsurface soil ingestion hazard index for RME receptors exceeds one primarily due to arsenic (1.49) and antimony

(0.84). The dermal contact exposure scenario primary risk driver and hazard index at SWMU 17A for CT and RME receptors is antimony (2.77 and 7.18, respectively). Arsenic, barium, cadmium and nickel hazard indices also contribute to the hazard index.

7.7.3.2 Carcinogenic Effects

7.7.3.2.1. The calculated cancer risks for the hypothetical future site worker groundwater ingestion and dermal contact scenario are within the USEPA target risk range primarily due to beryllium, for RME receptors. Beryllium was calculated to have ingestion exposure scenario cancer risks for the RME receptors of 2.32 x 10^{-5}. Dermal contact exposure scenario cancer risks for RME receptors are 1.06 x 10^{-5}.

7.7.3.2.2. The calculated cancer risks for the current site worker surface soil ingestion and dermal contact exposure scenarios are within the USEPA target risk range at SWMUs 17A and 17 B,C,D. The primary ingestion risk drivers and cancer risks for CT and RME receptors at SWMU 17A are arsenic (2.67 x 10^{-6} and 5.33 x 10^{-5}) and beryllium (7.40 x 10^{-8} and 1.48 x 10^{-6}). These chemicals also have cancer risks within the target risk range for dermal contact with surface soils at SWMU 17A. The primary dermal contact risk drivers and cancer risks for CT and RME receptors at SWMU 17 B,C,D are also arsenic (1.16 x 10^{-6} and 1.51 x 10^{-5}) and beryllium (1.34 x 10^{-5} and 1.74 x 10^{-4}). Calculated cancer risks for site worker ingestion of surface soil at SWMU 17 B,C,D are also within the USEPA target risk range of 1 x 10^{-4} to 1 x 10^{-6}, primarily due to arsenic and beryllium.

7.7.3.2.3. Cancer risks for the hunter surface soil exposure scenarios are within the target risk range for ingestion of surface soils at SWMUs 17A and 17 B,C,D. The primary risk driver and calculated cancer risk for the RME at SWMU 17A is arsenic (1.66 x 10^{-5}). At SWMU 17 B,C,D, the primary risk drivers and calculated cancer risks for RME receptors are also arsenic (7.88 x 10^{-6}) and beryllium (1.32 x 10^{-6}). The dermal contact exposure scenario also shows cancer risks within the target risk range for CT and RME receptors at SWMU 17A, primarily due to beryllium (1.05 x 10^{-6} and 1.15 x 10^{-5}). Beryllium is also contributing to the risk for this exposure scenario at SWMU 17 B,C,D. The calculated cancer risks for CT and RME receptors are 3.02 x 10^{-6} and 3.29 x 10^{-5}, respectively.

7.7.3.2.4. Construction worker cancer risks are within the target risk range for the dermal contact with surface soil exposure scenario at SWMUs 17A and 17 B,C,D. Primary risk drivers and cancer risks for CT and RME receptors at SWMU 17A are arsenic (4.91×10^{-7} and 2.55×10^{-6}) and beryllium (9.35×10^{-7} and 4.85×10^{-6}). The risk drivers and cancer risks for CT and RME receptors at SWMU 17 B,C,D are also arsenic (2.33×10^{-7} and 1.21×10^{-6}) and beryllium (2.68×10^{-6} and 1.39×10^{-5}). The ingestion of surface soil exposure scenario also exhibits cancer risks within the target risk range at these SWMUs for RME receptors. At SWMU 17A, the risk driver is arsenic, and at SWMU 17 B,C,D, the risk drivers are arsenic and beryllium. Calculated cancer risks for the construction worker ingestion of subsurface soil exposure scenario are also within the target risk range for SWMU 17A. The primary risk driver is arsenic, with CT and RME receptor cancer risks being 9.95×10^{-7} and 1.91×10^{-5}, respectively. At SWMU 17A, the dermal contact with subsurface soil is also within the target risk range with the primary risk driver being beryllium. CT and RME receptor cancer risks are 7.02×10^{-6} and 3.64×10^{-5}. The RME receptor cancer risk for the subsurface soil ingestion exposure scenario at SWMU 17 B,C,D is also within the target risk range, due to arsenic.

7.7.4 Uncertainty Analysis

7.7.4.0.1. Data collection/evaluation uncertainty may be relevant at SWMU 17 due to the types and numbers of samples collected and evaluated. As a conservative measure, all anthropogenic chemicals detected in surface soils at SWMU 17A were included in the risk evaluation, regardless of whether RBCs were exceeded. This was performed to allow the final risk calculations to determine the risk drivers for the site. In addition, data from the January groundwater sampling event was included that was not detected during the July sampling event (e.g., antimony). These determinations concerning the inclusion of data to be evaluated may overestimate the risk for this site.

7.7.4.0.2. Many metals detected at this site in groundwater, surface and subsurface soils are naturally occurring and in some cases (i.e., subsurface soil), statistical methods were used to distinguish site-related from non-site-related metals. All metals detected in groundwater and surface soil were included for evaluation in the final risk calculations, due to the absence of background data in these media. This may overestimate the risk for this site.

7.7.4.0.3. The hunter scenario was included for evaluation in the risk evaluation as a potentially complete exposure pathway. SWMU 17 is an active area of the plant, and is located inside the RAAP boundaries; therefore, it is presently not accessible by recreational hunters. The dermal contact and ingestion of surface soils exposure scenarios exhibit risk for this receptor. As with all modeled concentrations and exposure scenarios, there are assumptions based on best professional judgement and this may over- or underestimate risk.

7.7.4.0.4. Another area of uncertainty in evaluating human health risk from SWMU 17 is toxicity assessment. Oral and dermal slope factors are not available for some of the metals (i.e., lead) and semivolatiles which were detected in groundwater and subsurface soils. However, lead generally exists in a state that is relatively immobile unless site soil conditions approach very high or low pH. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

7.8 RISK SUMMARY

7.8.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for various receptors potentially exposed to multiple chemicals in groundwater, surface and subsurface soils. These calculations are summarized and presented in Tables 7.9 and 7.10. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 1×10^{-4} to 1×10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 1×10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index below one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

7.8.0.2. At SWMUs 17A and 17 B,C,D, the site worker CT and RME receptors' total hazard index is greater than one for RME receptors and the cancer risk is within the target risk range. The RME receptor exposure scenario exceeds the target cancer risk range for both SWMUs. These values indicate a potential for carcinogenic adverse human health effects for this receptor.

7.8.0.3. The hunter CT and RME receptors' total hazard index is less than one at SWMUs 17A and 17 B,C,D. The cancer risk for these receptors is within the target risk

Table 7.9
Summary of Human Health Risk
SWMU 17A
Radford Army Ammunition Plant

Receptor	Pathways	HI		Cancer Risk	
		CT	RME	CT	RME
Site Worker	Ingestion of Groundwater	0.26	1.02	1.16E-06	2.32E-05
	Dermal Contact with Groundwater	0.12	0.46	5.27E-07	1.06E-05
	Ingestion of Surface Soil	0.09	0.35	2.74E-06	5.48E-05
	Dermal Contact with Surface Soil	0.19	0.5	7.13E-06	9.25E-05
	Inhalation of Surface Soil Particulates	0	0	6.61E-14	9.96E-13
Total for Site Worker		0.66	2.33	1.16E-05	1.81E-04
Hunter	Ingestion of Surface Soil	0.02	0.06	9.86E-07	1.71E-05
	Dermal Contact with Surface Soil	0.02	0.05	1.61E-06	1.75E-05
Total for Hunter		0.04	0.11	2.60E-06	3.46E-05
Construction Worker	Ingestion of Surface Soil	0.35	1.70	1.10E-06	2.10E-05
	Dermal Contact with Surface Soil	0.39	0.50	1.43E-06	7.40E-06
	Inhalation of Surface Soil Particulates	0	0	3.19E-14	2.23E-13
	Ingestion of Subsurface Soil	0.64	3.06	4.99E-07	1.92E-05
	Dermal Contact with Subsurface Soil	3.47	8.99	2.89E-07	3.00E-06
	Inhalation of Subsurface Soil Volatiles	0	0	8.85E-09	1.07E-07
	Inhalation of Subsurface Soil Particulates	0	0	6.40E-15	7.70E-14
Total for Construction Workers		4.85	14.25	3.33E-06	5.07E-05

Table 7.10
Summary of Human Health Risk
SWMU 17BCD
Radford Army Ammunition Plant

Receptor	Pathways	HI		Cancer Risk	
		CT	RME	CT	RME
Site Worker	Ingestion of Groundwater	0.26	1.02	1.16E-06	2.32E-05
	Dermal Contact with Groundwater	0.12	0.46	5.27E-07	1.06E-05
	Ingestion of Surface Soil	0.04	0.17	1.47E-06	2.95E-05
	Dermal Contact with Surface Soil	0.09	0.23	1.45E-05	1.89E-04
	Inhalation of Surface Soil Particulates	0	0	3.21E-14	4.83E-13
Total for Site Worker		0.51	1.88	1.77E-05	2.52E-04
Hunter	Ingestion of Surface Soil	0.01	0.03	5.31E-07	9.20E-06
	Dermal Contact with Surface Soil	0.01	0.02	3.28E-06	3.57E-05
Total for Hunter		0.02	0.05	3.81E-06	4.49E-05
Construction Worker	Ingestion of Surface Soil	0.17	0.80	5.90E-07	1.13E-05
	Dermal Contact with Surface Soil	0.17	0.23	2.91E-06	1.51E-05
	Inhalation of Surface Soil Particulates	0	0	1.55E-14	1.08E-13
	Ingestion of Subsurface Soil	0.03	0.13	8.52E-08	1.64E-06
	Dermal Contact with Subsurface Soil	0.01	0.01	3.93E-08	2.04E-07
	Inhalation of Subsurface Soil Particulates	0	0	2.49E-15	1.74E-14
Total for Construction Workers		0.38	1.17	3.62E-06	2.82E-05

range for CT and RME receptors at these SWMUs. These values indicate a potential for carcinogenic adverse human health effects for this receptor.

7.8.0.4. The construction worker CT and RME receptors' total hazard index is greater than one at SWMU 17A. The RME receptor hazard index is greater than one at SWMU 17B,C,D. The CT and RME receptors' cancer risk is within the target risk range at both SWMUs. These values indicate a potential for noncarcinogenic and carcinogenic adverse human health effects at SWMUs 17A, and 17B,D,D.

7.9 SWMU 17/40 SUMMARY

7.9.0.1. SWMU 17 is subdivided into five separate areas based on history, operations, and topography. SWMU 17A located in the western-most of two significant sinkholes was considered separately, while SWMUs 17B,C,D,E located in the eastern sinkhole, were considered together. SWMU 40 was grouped with SWMU 17 because of their proximity and similar subsurface conditions. Only groundwater was characterized for SWMU 40.

7.9.0.2. The groundwater associated with SWMU 17/40 is contained within the fractured dolomite of the karst aquifer underlying the SWMU. Although the groundwater flow direction appears to be west-northwest toward the New River, groundwater movement and occurrence in this area can be unpredictable because of the karst features. A dye tracing study demonstrated a connection between groundwater at the western sinkhole (SWMU 17A) and a spring located on the bank of the New River.

7.9.0.3. Groundwater, surface soil, and subsurface soil samples were collected to characterize SWMU 17/40. The sampling of the spring was included with the New River discussion in Section 12. Barium, antimony, and beryllium were identified as the COC compounds for groundwater at SWMU 17/40. Barium was found in the samples from all four wells; beryllium, which was a risk driver, was detected in the samples from two of the four wells. Antimony, a risk driver, was only detected in one well during the January 1995 sampling event; this metal was not detected during the July 1995 sampling event. Only a minimal barium detection was found in the sample from the well directly downgradient of the SWMUs (as determined by the results of the dye tracing study). This may indicate a narrow, laterally limited, groundwater preferential migration pathway. Contaminants detected in the soils and groundwater at SWMU 17 (particularly the risk driver compound beryllium) were also found in the spring surface water and sediment samples, demonstrating a migration of contaminants from the SWMU to the New River.

7.9.0.4. Arsenic and beryllium were identified as the risk driver compounds for surface soils at SWMU 17A; arsenic and antimony were risk driver compounds for subsurface soils. The highest metals concentrations were found in the near surface sample from the boring nearest the active burning operations. Arsenic and beryllium were also determined to be the risk driver compounds for surface soils at SWMU 17B,C,D. Most of the surface soil high metals concentrations in this SWMU were from one sample (17BSS1). Arsenic was the risk driver compound for subsurface soils at SWMU 17B,C,D. The maximum concentration was in the near surface sample from boring 17CSB1.

7.9.0.5. The human health risk assessment indicated a potential for noncarcinogenic or carcinogenic adverse human health effects for ingestion or dermal contact of groundwater, surface soil, or subsurface soil by site workers, construction workers, or hunters.

SECTION 8

SITE CHARACTERIZATION OF SWMU 31 (COAL ASH SETTLING LAGOONS)

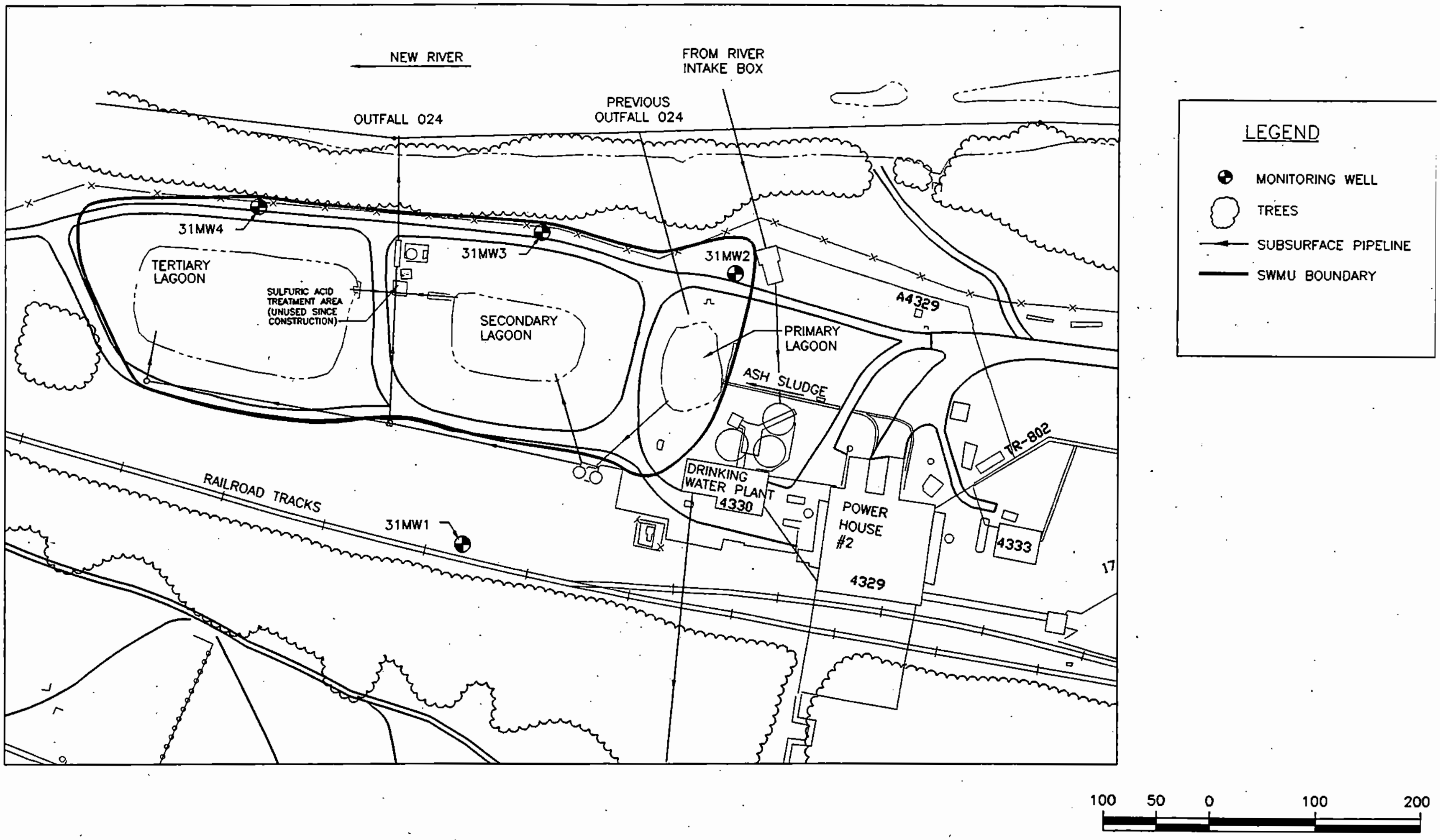
8.1 HISTORY AND OPERATIONS

8.1.0.1. The Coal Ash Settling Lagoons (SWMU 31) are located in the northwest section of the Horseshoe Area. Plate 1 shows SWMU 31 in relation to the rest of the facility. A detailed location map of SWMU 31 is presented as Figure 8.1. The unit has previously been referred to as both the "fly ash settling lagoon" and the "bottom ash settling lagoon." The SWMU has been referred to as the Coal Ash Settling Lagoons throughout this investigation, reflecting the probability that both fly ash and bottom ash have been discharged into it. In addition, the flocculating basin underdrainage and filter backwash water from Water Plant 4330 reportedly flowed to this unit (USATHAMA, 1976).

8.1.0.2. SWMU 31 is associated with Power House No. 2, which burned low sulfur coal to supply steam at 150 pounds per square inch (psi) to the buildings in the Horseshoe Area. Power House No. 2 has not been active for approximately two years. Prior to 1971, when electrostatic precipitators were installed at the power house, fly ash contaminated wastewater was discharged directly to the New River (USATHAMA, 1984).

8.1.0.3. SWMU 31 consists of three unlined settling lagoons. During active use of Power House No. 2, water carrying fly ash from the power house flowed down a below-grade, concrete-lined sluice waterway to the small primary settling lagoon (approximately 100 feet long by 50 feet wide), which was constructed in 1962. At one time, the supernatant from the primary settling lagoon was emptied directly into the New River via Outfall 024 (Permit No. VA 0000248). In 1978 or 1979, additional components were added to the unit; wastewater now flows from the primary settling lagoon through a below-ground pipe to a concrete sump. The sump is 18 to 20 feet deep, 2 feet of which is above grade. From the concrete sump, water is discharged to the secondary settling lagoon, which is approximately 150 feet wide by 200 feet long. From the secondary settling lagoon, water is discharged to the tertiary settling lagoon (approximately 150 feet wide by 250 feet long).

FIGURE 8.1
SWMU 31 LOCATION MAP (COAL ASH SETTLING LAGOONS)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



722843/28435R_1 10/1/95

8.1.0.4. Facility representatives indicate that the water currently flowing into the primary settling lagoon consists of either overflow from the drinking water settling tanks or backwash from the cleaning of the filters at the drinking water settling tanks. On average, 20,000 gallons of overflow water per day is released to the primary lagoon at a relatively constant flow rate. At a minimum, the filters require cleaning once every three days. This process involves passing 2800 gallons of water per minute through the filters for 20 minutes to remove accumulated river sediment. The 56,000 gallons of turbid sediment-rich water yielded by this process is discharged to the primary settling lagoon. The yield is then split so that equal volumes of this water are discharged to the secondary and tertiary settling lagoons.

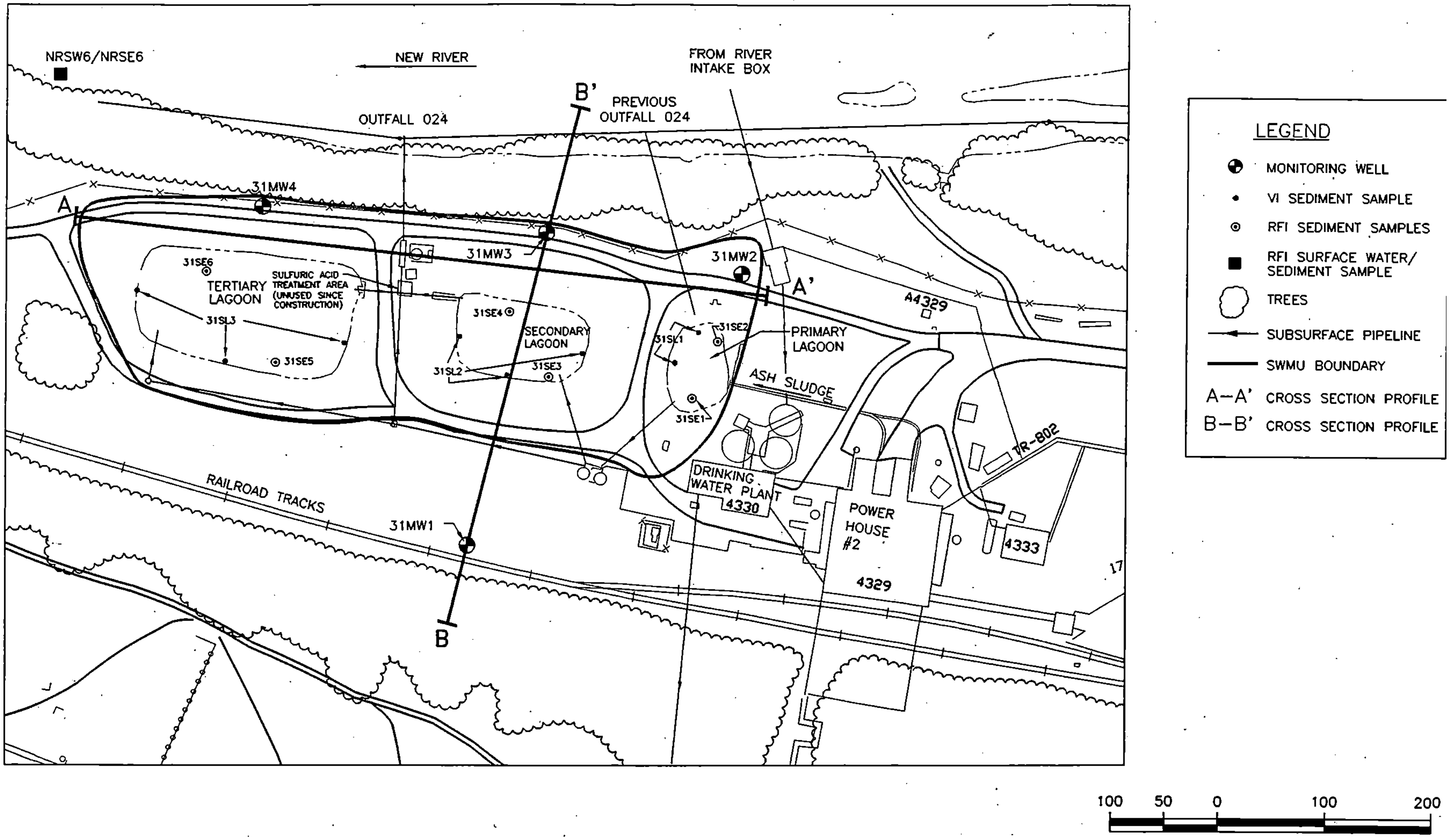
8.1.0.5. The effluent from the tertiary settling lagoon is designed to discharge to the New River through the new location of Outfall 024 following pH adjustment with sulfuric acid. However, facility representatives indicate that there has never been a discharge. All water discharged to the basin apparently percolates through the basin into the surrounding soils or evaporates.

8.1.0.6. Coal ash that settled out in the three lagoons was periodically dredged and disposed in Fly Ash Landfill (FAL) No. 2 (SWMU 29). Previously, coal ash was disposed in FAL No. 1 (SWMU 26).

8.2 PREVIOUS INVESTIGATIONS

8.2.0.1. A waste characterization study was conducted at SWMU 31 by Dames & Moore in February 1992. During this study, three composite sediment samples were collected, one from each of the three lagoons (Figure 8.2). Samples were collected from the top one foot of sludge beneath the water/sludge interface along the edges of the lagoons. Two of the samples (31SL2 and 31SL3) were composited from three subsample locations in the secondary and tertiary lagoons respectively, and the third sample (31SL1) was composited from two subsample locations in the primary lagoon. These samples plus one duplicate were analyzed for metals and semivolatile organic compounds (SVOCs). No other types of samples were collected at this SWMU. The results of the 1992 sediment sampling are summarized in Table 8.1. Also included in the summary table are the HBNs from the RCRA permit (USEPA, 1989a), comparison levels of soil background data calculated by Dames & Moore (1992a), and RBCs for commercial and industrial soils (USEPA, 1994).

FIGURE 8.2
SWMU 31 SAMPLE LOCATION MAP (COAL ASH SETTLING LAGOONS)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



72843/28437/8_1 12/4/95

PARSONS ENGINEERING SCIENCE, INC.

TABLE 8.1
VI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR SEDIMENT SAMPLES COLLECTED AT SWMU 31
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 25 Feb 92 - 10 Mar 92 1.0 ft	Alluvial Soil Background Comparison Level*	HBN	RBC Industri[al] Soil
TAL Inorganics (µg/g)						
Aluminum	14.1	4	8,770 - 18,900	18,275	230,000	1,000,00[0]
Arsenic	30	4	[4.59] - [9.78]	9.01	0.5	1.6
Barium	1	4	80.8 - 149	209	1,000	72,000
Beryllium	0.2	4	[1.41] - [2.33]	0.90	0.1	0.67
Calcium	100	4	1,790 B - 3,980 B	89,890	NSA	NA
Chromium	4	4	11.1 - 34.2	25.67	400	1,000,00[0]
Cobalt	3	4	[8.16] - [16.1]	18.21	0.8	NA
Copper	7	4	26.4 - 32.9	45.65	2,900	38,000
Iron	1,000	4	7,380 - 33,300	47,506	NSA	NA
Lead	2	4	LT 10.5 - 19.7	292.14	200	NA
Magnesium	50	4	951 - 6,620	38,682	NSA	NA
Manganese	0.275	4	134 - 664	2,236	8,000	5,100
Mercury	0.1	4	LT 0.05 - 0.142	0.05	20	310
Nickel	3	4	18.7 - 22.5	29.68	1,000	20,000
Potassium	37.5	4	576 - 2,650	4,532	NSA	NA
Selenium	40	4	LT 0.25 - 0.882	0.57	200	5,100
Silver	4	4	LT 0.589 - 1.23	1.88	200	5,100
Sodium	150	4	328 B - 541 B	399	NSA	NA
Thallium	20	4	LT 6.62 - [14.5]	6.62	6	NA
Vanadium	0.775	4	21.2 - 64.5	41.49	560	7,200
Zinc	30.2	4	38.6 - 95.8	942	16,000	310.000
Semivolatiles (µg/g)						
1,2-Dichlorobenzene	0.01	4	LT 0.11 - 3.46	NT	1,000	92,000
2-Methylnaphthalene	0.3	4	1.15 - 1.53	NT	NSA	NA
Dibenzofuran	0.3	4	LT 0.035 - 0.285	NT	NSA	NA
Fluoranthene	0.3	4	LT 0.068 - 0.157	NT	500	41,000
Fluorene	0.3	4	LT 0.033 - 0.09	NT	3,200	41,000
Naphthalene	0.3	4	0.092 - 1.42	NT	1,000	41,000
Phenanthrene	0.5	4	0.078 - 1.26	NT	40	NA

TABLE 8.1 (CONTINUED)
VI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR SEDIMENT SAMPLES COLLECTED AT SWMU 31
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 25 Feb 92 - 10 Mar 92 1.0 ft	Alluvial Soil Background Comparison Level*	HBN	RBC Industri[a]l Soil
Semivolatile TICs (μg/g)						
1-Methylnaphthalene	NA	4	ND - 0.917 S	NT	NSA	NA
2,6,10,14-Tetramethylpentadecane	NA	4	ND - 4.88 S	NT	NSA	NA
Cyclohexene Oxide	NA	4	ND - 0.296 SB	NT	NSA	NA
Decane	NA	4	ND - 0.55 S	NT	NSA	NA
Heneicosane	NA	4	ND - 0.55 S	NT	NSA	NA
Heptadecane	NA	4	ND - 0.917 S	NT	NSA	NA
Hexadecanoic Acid, Butyl Ester	NA	4	ND - 7.61 S	NT	NSA	NA
Octadecanoic Acid, Butyl Ester	NA	4	ND - 5.08 S	NT	NSA	NA
Pentacosane	NA	4	ND - 2.44 S	NT	NSA	NA
Tridecane	NA	4	ND - 0.734 S	NT	NSA	NA
Total Unknown TICs	NA	4	ND - (5)383	NT	NSA	

* Alluvial soil samples were collected from 5 locations at RAAP. The mean and standard deviations were calculated. Background comparison levels we[re] selected from the upper 95 percent confidence interval of the background data set, which is equal to the mean plus two standard deviations.
** Chromium II and compounds.
B Analyte was detected in corresponding method blank; values are flagged if the sample concentration is less than 10 times the method blank concentratio[n] for common laboratory constituents and 5 times for all other constituents.
HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumption[s] consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
LT Concentration is reported as less than the certified reporting limit.
NA Not available; PQLs are not available for TICs detected in the library scans.
ND Analyte was not detected.
NT Not tested.
NSA No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given anaytical method.
S Results are based on an internal standard; flag is used for TICs detected in library scans.
TAL Target analyte list.
TICs Tentatively identified compounds that were detected in the GC/MS libarary scans.
μg/g Micrograms per gram.
( ) Parentheses indicate the number of unknown TICs that were detected in either the volatile or semivolatile GC/MS library scans. The number beside th[e] parentheses is the total concentration of all TICs detected in each respective scan.
[ ] Brackets indicate that the detected concentration exceeds the HBN.

From Dames & Moore, 1992b

8.2.0.2. The results of the chemical analyses for metals and SVOCs indicated that concentrations of arsenic and beryllium exceeding HBN and RBC criteria, and cobalt exceeding HBN criteria were found in all three samples. Thallium was also detected at a concentration above the HBN in sample 31SL2. The arsenic and cobalt levels were less than or slightly greater than the background soil criteria. Several other metals such as aluminum, chromium mercury, selenium, and vanadium were detected at concentrations above background levels but below HBNs and RBCs. Several SVOCs and SVOC tentatively identified compounds (TICs) were detected but not at levels above HBNs or RBCs.

8.3 SUMMARY OF RFI FIELD ACTIVITIES

8.3.0.1. To determine the migration of any metals from the lagoons, three downgradient and one upgradient groundwater monitoring well was installed at SWMU 31. Two soil samples were collected from each well boring. During the drilling of the 31MW1 boring, one sample was collected in a Shelby tube for geotechnical testing.

8.3.0.2. Groundwater samples were collected from each well. Field measurements of the groundwater were taken. To determine potential disposal characteristics of the lagoon sediments, two composite sediment samples representing the total sediment column were collected from each lagoon. The analytical parameters for these samples are shown in Tables 4.3 and 4.4. The sample locations are shown in Figure 8.2. A summary of the field activities for SWMU 31 is presented in Table 8.2.

8.3.0.4. After installation of the wells, an aquifer slug test (insertion and removal) was conducted on the newly-installed wells to evaluate potential migration rates and other hydrogeologic characteristics. In addition, each well was surveyed to determine elevation and location coordinates. Staff gauges were placed in each of the lagoons. These gauges were surveyed to facilitate the study of groundwater flow from the lagoons to the river. All of these field activities were completed in January 1995.

TABLE 8.2

SUMMARY OF SWMU 31 RFI FIELD ACTIVITIES

RADFORD ARMY AMMUNITION PLANT

SWMU	Monitoring Wells Installed and Sampled*	Well Boring Samples	Depth (Feet Below Ground Surface)	Sediment Samples	Geotechnical Samples/ Depth	Slug Tests	Staff Gauges Installed
31	31MW1	31MW1A25	23-25	31SE1	31MW1(10-12)	31MW1	Primary Lagoon
	31MW2	31MW1B35	33-35	31SE2		31MW2	Secondary Lagoon
	31MW3	31MW2A12	10-12	31SE3		31MW3	Tertiary Lagoon
	31MW4	31MW2B22	20-22	31SE4		31MW4	
	31MW5 (Dup. of 31MW3)	31MW3A10	5-10	31SE5			
		31MW3B20	15-20	31SE6			
		31MW4A12	10-12				
		31MW4B22	20-22				
		31MW4C40 (Dup. Of 31MW4A12)					

* Field measurements of pH, temperature, and conductivity were also recorded.

8.4 ENVIRONMENTAL SETTING

8.4.1 Topography and Site Layout

8.4.1.1. SWMU 31 is located on a nearly level terrace adjacent to the New River at an approximate elevation of 1,700 feet above mean sea level. The New River flows from northeast to southwest along the northern boundary of the SWMU. The river is approximately 100 feet from the lagoons. The facility's New River water intake (No. 2) is approximately 300 feet upstream of Outfall 024.

8.4.1.2. Railroad tracks (inactive) run along the southern boundary of SWMU 31; the tracks are elevated approximately 15 feet above the level terrace. South of the tracks, the elevation increases further, so that the SWMU vicinity is a "stepped" terrace leading down to the New River.

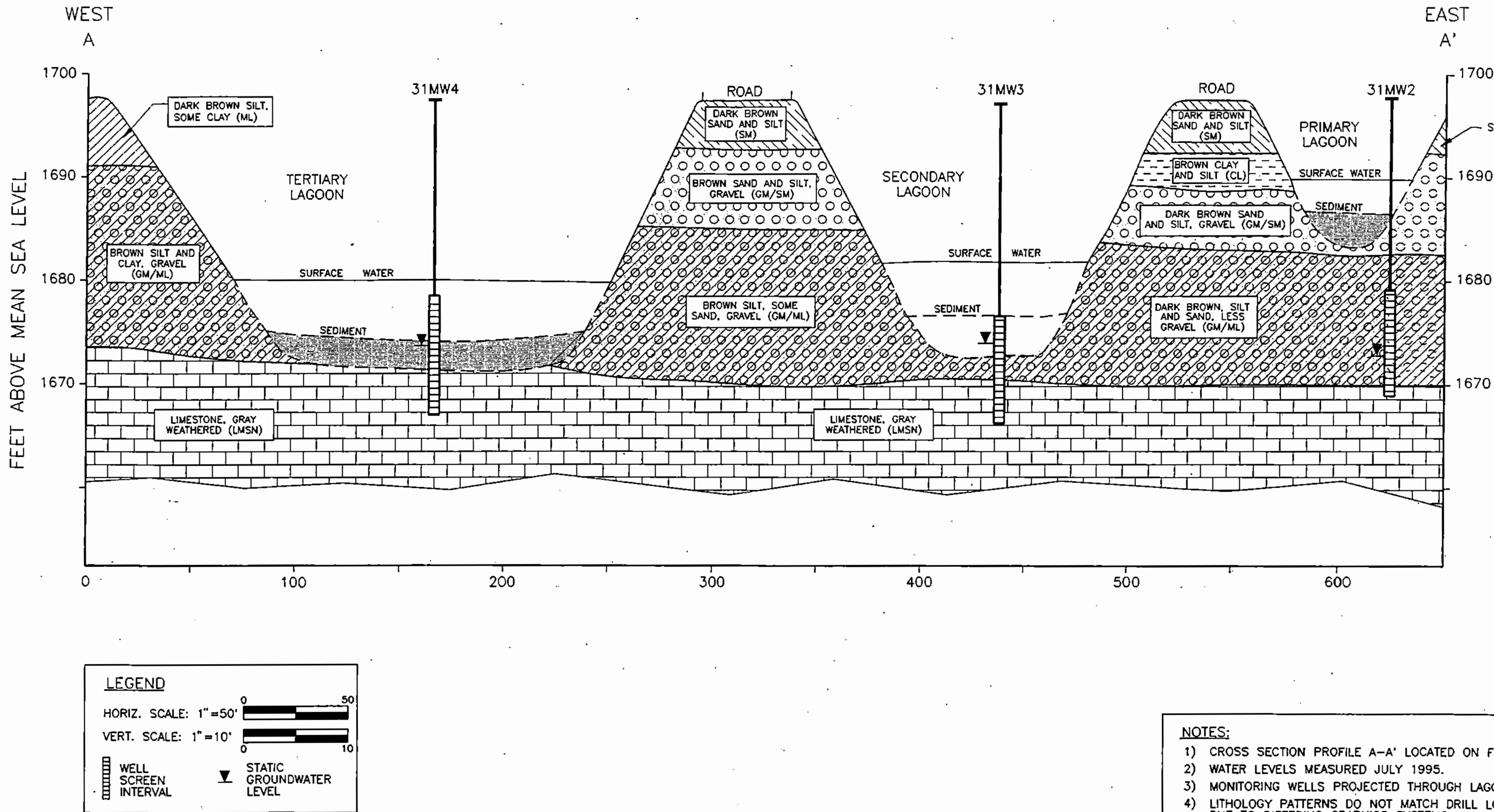
8.4.2 Geology

8.4.2.1. The geology of SWMU 31 was characterized by drilling four groundwater monitoring wells for the RFI. Samples were either collected continuously or at five foot intervals in each boring as described in section 4. The vertical extent of all investigatory drilling activities was approximately 53 feet, ranging from 1715 feet above mean sea level (amsl) to 1662 feet amsl.

8.4.2.2. All geological samples were categorized under the Unified Soil Classification System (USCS) in accordance with the work plan. One geotechnical sample was taken from monitoring well boring 31MW1 at 10-12 feet below ground surface (bgs) and submitted for laboratory analysis to determine USCS designation. All other samples, including those collected for chemical analysis or general site characterization, were given a USCS designation in the field by the project geologist. The compiled information was used to prepare the geologic cross sections presented as Figures 8.3 and 8.4. The cross section profile lines are shown on Figure 8.2.

8.4.2.3. The geology of SWMU 31 was consistent across the study area; the subsurface generally comprised unconsolidated alluvial sediments overlying the weathered limestone of the Elbrook Formation. The SWMU 31 vicinity displays the characteristic terraces of the unconsolidated sediments at RAAP. Cross section B-B' (Figure 8.4) reveals

FIGURE 8.3
SWMU 31 GEOLOGIC CROSS SECTION (A–A')
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

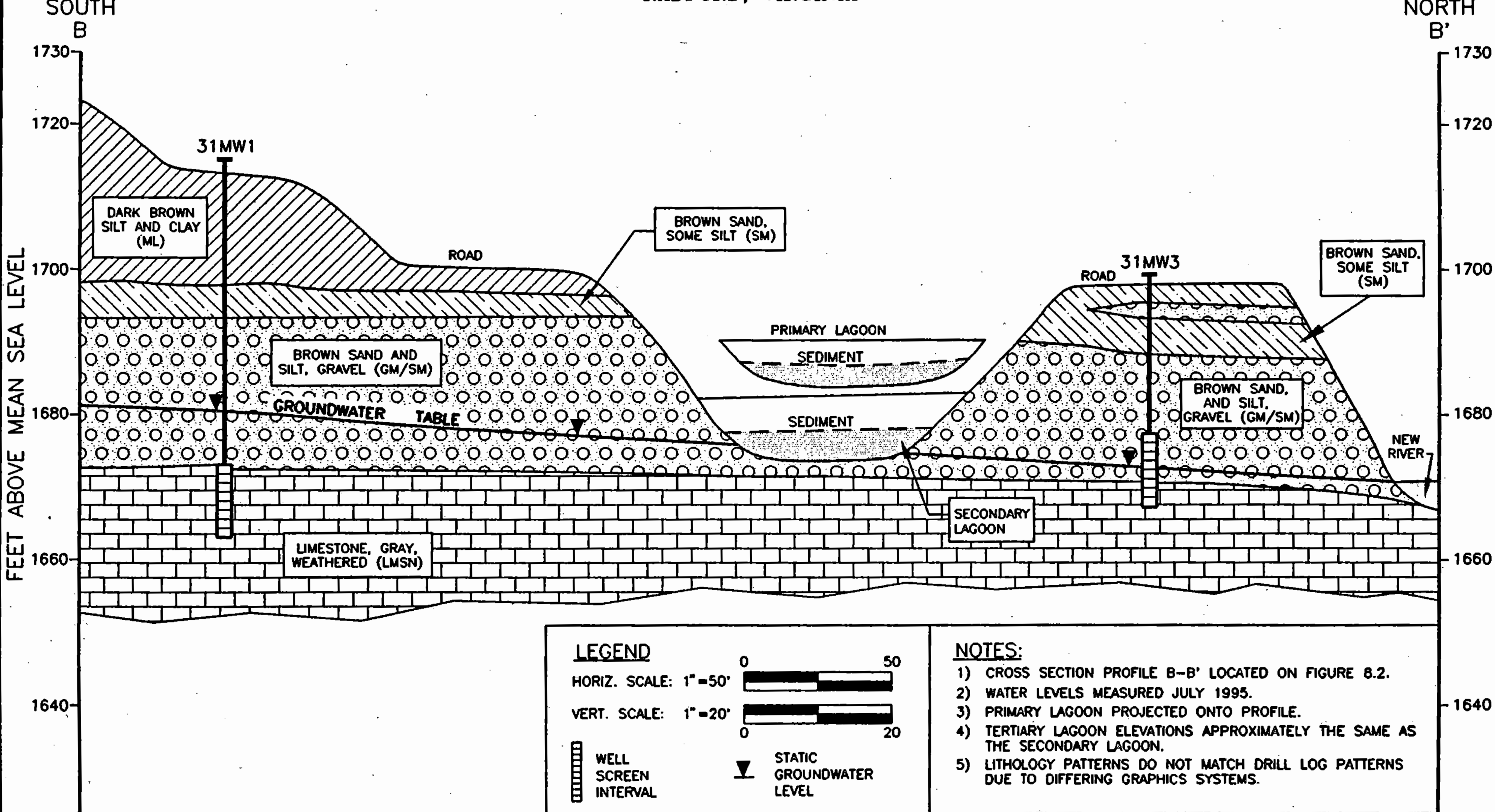


NOTES:
1) CROSS SECTION PROFILE A–A' LOCATED ON FIGURE 8.2.
2) WATER LEVELS MEASURED JULY 1995.
3) MONITORING WELLS PROJECTED THROUGH LAGOONS.
4) LITHOLOGY PATTERNS DO NOT MATCH DRILL LOG PATTERI DUE TO DIFFERING GRAPHICS SYSTEMS.

J:\CADD\722843\843FG8_3 12/4/95

PARSONS ENGINEERING SCIENCE INC

FIGURE 8.4
SWMU 31 GEOLOGIC CROSS SECTION (B–B')
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



0\722843\843FG8_4 12/4/95

the terraced morphology and the sediments gently dipping to the New River (south to north). There is a general fining upwards textural sequence as silts and clays overlie gravels and silty sands. Below the gravels and sands, the bedrock interface was encountered. The unconsolidated sediments were 25-28 feet thick along the New River as shown in the west to east cross section A-A' (Figure 8.3).

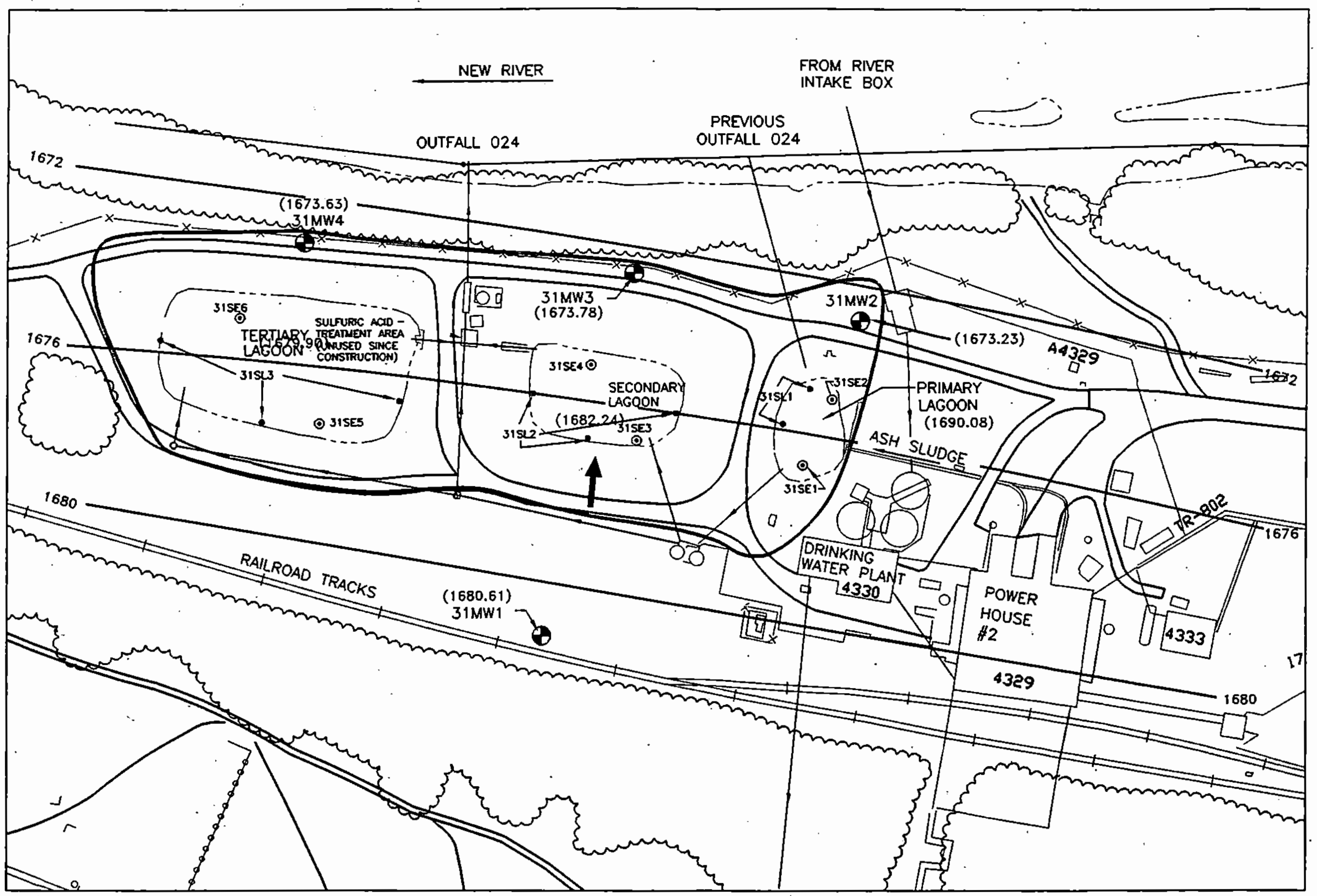
8.4.2.4. A dark brown silt layer containing varying amounts of clay (ML) was typically encountered overlying a silty sand (SM). At approximately 6-8 feet bgs, a dark brown sand, silt, and gravel layer (GM/SM) was present. It was 5-7 feet thick. Below this layer was a brown silt, clay, and gravel (GM/ML) section, which extended to the bedrock interface. To the west, the GM/SM interval was absent. To the east, a brown clay layer (CL) was observed at 5-8 feet bgs between well borings 31MW3 and 31MW2. The GM layers often contained the cobbles or boulders (river jack) that occur throughout the alluvial strata along the river. The bedrock was a gray weathered limestone which was partially penetrated by hollow stem augers in some borings, but which required air drilling methods to complete the wells in other borings. The rock samples at the bedrock interface were determined to be limestone by hydrochloric acid effervescence testing.

8.4.3. Hydrogeology

8.4.3.0.1. Three of the four wells installed at SWMU 31 (31MW2, 32MW3, and 31MW4) were screened in the alluvial sediments overlying the Elbrook Formation bedrock. The fourth well (31MW1) was screened at the bedrock interface. Groundwater was encountered approximately 23 feet bgs at wells 31MW2, 31MW3 and 31MW4, which are located along the New River. 31MW1 was installed on the terrace approximately 15 feet higher in elevation than the other three wells at this site; groundwater was encountered at approximately 32 feet bgs in this well.

8.4.3.0.2. Groundwater occurrence and movement does not appear to be complex at this SWMU. Groundwater is present within a relatively shallow unconfined aquifer consisting of unconsolidated alluvial sediments overlying the Elbrook limestone. The potentiometric surface of the groundwater at SWMU 31 is shown in cross section in Figures 8.3 (perpendicular to flow direction) and 8.4 and in plan view in Figure 8.5. Groundwater elevations have been observed to fluctuate seasonally from 2-7 feet at this SWMU (January

FIGURE 8.5
SWMU 31 GROUNDWATER POTENTIOMETRIC SURFACE MAP
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



LEGEND

1673.78	MONITORING WELL GROUNDWATER ELEVATION
	TREES
	SUBSURFACE PIPELINE
	SWMU BOUNDARY
~1676 ~	POTENTIOMETRIC SURFACE (FT AMSL)
	APPARENT GROUNDWATER FLOW DIRECTION

NOTES: 1. GROUNDWATER ELEVATIONS FOR ALL WELLS MEASURED ON 7/13/95.
LAGOON SURFACE WATER ELEVATIONS MEASURED ON 7/15/95

100 50 0 100 200

SCALE: 1"=100'

722843/2843F8_1 12/4/95

PARSONS ENGINEERING SCIENCE, INC.

and July measurements). The groundwater elevations presented in the figures are from the July 1995 sampling event.

8.4.3.0.3. Subsurface conditions in the vicinity of 31MW1 were slightly different than for the wells along the river. Although the same layers were encountered at similar elevations, the GM/SM layer was considerably drier in this area than near the river. The well boring was advanced into a wet zone of the bedrock to ensure that the well would not be dry. The result was a screened interval lower than the other wells. After approximately 24-36 hours, the groundwater stabilized above the screen as shown in Figure 8.4. The groundwater potentiometric level in this area is consistent with flow toward the river, but the overburden may contain more clay, or the bedrock may have fewer fractures, resulting in slower recharge of groundwater in 31MW1. Since light non-aqueous phase liquid compounds (floaters) are not a contaminant of concern at this SWMU, the stabilized groundwater level relative to the top of the screen is not significant in this well.

8.4.3.0.4. The direction of groundwater flow at SWMU 31 is north to northwest, toward the New River. The hydraulic gradient is approximately 0.01 ft/ft. The potentiometric surface of the groundwater is approximately the same elevation as the secondary and tertiary lagoon sediment levels. Since these lagoons were excavated to the bedrock surface, the bottoms of the lagoons are essentially at the groundwater table; the surface water elevations of these two lagoons are consistently above the groundwater table, although the discharge of water into the lagoons from the drinking water settling tanks (Subsection 8.4.4) contributes to this condition. The primary lagoon was constructed at a higher elevation. The relationships between groundwater and sediment and surface water levels in the lagoons can be seen in the cross sections.

8.4.3.0.5. Well construction details for the SWMU 31 monitoring wells are shown in Table 4.1. Field data collected during the January and July 1995 sampling events is summarized in Table 8.3. Field data included the groundwater elevations used to prepare Figure 8.5, photoionization detector (PID) readings of the well headspace in parts per million (ppm), pH, temperature, and conductivity of the groundwater.

TABLE 8.3
SWMU 31: GROUNDWATER FIELD DATA
RADFORD ARMY AMMUNITION PLANT

Well Name	Date	Depth to Bottom (ft)	Depth to Water (ft)	Groundwater Elevation*(ft)	PID (ppm)	pH	Temperature (degrees F)	Conductivity (us/cm)
31MW1	1-17-95	52.40	32.36	1682.68	0.3	7.21	65.5	660
31MW2	1-17-95	28.50	19.62	1679.43	3.2	7.95	65.1	560
31MW3	1-17-95	32.43	18.76	1680.82	2.2	7.25	60.7	570
31MW4	1-17-95	30.45	20.15	1678.40	30.1	7.52	64.2	580
31MW1	7-15-95	52.40	34.43	1680.61	0.0	7.10	73.3	725
31MW2	7-15-95	28.50	25.82	1673.23	0.0	7.17	91.2	2.2
31MW3	7-15-95	32.43	25.04	1673.78	0.0	7.29	NA	1.02
31MW4	7-15-95	30.45	24.92	1673.63	0.0	7.94	80.0	347

* Feet above mean sea level
NA: No data due to instrument malfunction.

8.4.3.1 Aquifer Testing Results

8.4.3.1.1. In order to further investigate the groundwater characteristics at SWMU 31, four falling-head (injection) and two rising-head (withdrawal) slug tests were conducted on wells 31MW1 through 31MW4 in January 1995 as discussed in section 4.7. Data are included for falling-head slug tests 31MW3 and 31MW4, however the results were deemed invalid due to quick recharge resulting from a heavy rainstorm.

8.4.3.1.2. All four wells intercept groundwater flow from a shallow, unconfined zone of unconsolidated alluvial sediments. The bottom of the screened interval is positioned in the bedrock for all wells; the screen of 31MW1 is almost entirely in the bedrock. The hydraulic conductivity and transmissivity data for these wells are summarized in Table 8.4; calculations and type curves from the slug test data are located in Appendix E.

8.4.3.1.3. The highest hydraulic conductivity value calculated at SWMU 31 was at well 31MW2 (2.11×10^{-4} cm/sec or 0.6 ft/day). The lowest hydraulic conductivity value at SWMU 31 was at 31MW4 (9.18×10^{-6} cm/sec or 0.026 ft/day). The average hydraulic conductivity calculated at SWMU 31 (7.80×10^{-5} cm/sec) falls into the range of silt, loess, or silty sand for unconsolidated deposits or alluvium (Freeze and Cherry, 1979). The hydraulic conductivity value of 8.15×10^{-5} cm/sec for 31MW1, which more fully penetrates the bedrock, falls into the silt and loess range (unconsolidated) and into the limestone and dolomite range (bedrock).

8.4.3.1.4. Transmissivity, the rate at which water moves through a unit width of aquifer material under a unit hydraulic gradient, is the product of hydraulic conductivity and aquifer thickness. The highest transmissivity value calculated at SWMU 31 was in well 31MW2 (11.98 ft^2/day), and the lowest was in well 31MW4 (0.52 ft^2/day). The average calculated transmissivity value for SWMU 31 is 4.65 ft^2/day.

8.4.3.1.5. The horizontal groundwater flow velocity can be calculated by using the average hydraulic conductivity (7.80×10^{-5} cm/sec), the hydraulic gradient (1 percent) as measured from Figure 8.5, and an estimated effective porosity of 35 percent. The estimated porosity of 35 percent for the unconsolidated layer is based on a range of porosities typical for unconsolidated sand and silt mixtures (Freeze and Cherry, 1979). By using the Darcy

TABLE 8.4

SUMMARY OF SLUG TESTING DATA
SWMU 31 (COAL ASH SETTLING LAGOONS)

RADFORD ARMY AMMUNITION PLANT

WELL	TEST DATE	SLUG TEST TYPE	HYDRAULIC CONDUCTIVITY (K) IN:		TRANSMISSIVITY (t) FT^2/DAY
			FT/MIN	CM/SEC	
31MW1	1-12-95	Injection/falling-head	1.61×10^{-4}	8.15×10^{-5}	4.62
31MW2	1-12-95	Injection/falling-head	4.16×10^{-4}	2.11×10^{-4}	11.98
31MW3	1-11-95	Injection/falling-head	1.02×10^{-5}	5.30×10^{-6}	0.30
31MW3	1-12-95	Withdrawal/rising-head	2.03×10^{-5}	1.03×10^{-5}	1.47
31MW4	1-11-95	Injection/falling-head	1.16×10^{-3}	5.90×10^{-4}	33.4
31MW4	1-12-95	Withdrawal/rising	$1.82 \text{ X } 10^{-5}$	$9.18 \text{ X } 10^{-6}$	0.52
		Average for SWMU 31*:	1.54×10^{-4}	7.80×10^{-5}	4.65

* The averages do not include 31MW3 and 31MW4 injection/falling-head tests, as a heavy rainstorm significantly affected those test results.

Equation and standard equation of hydraulics (V=Ki/n) where V is velocity, K is hydraulic conductivity, i is the hydraulic gradient, and n is effective porosity, the estimated groundwater flow velocity was calculated to be 2.23 x 10^{-6} cm/sec or 2.31 ft/yr.

8.4.4 Surface Water

8.4.4.1. The New River is approximately 70 feet northwest of the boundary of SWMU 31, and about 30 feet lower in elevation. The New River in this vicinity flows parallel to SWMU 31 from northeast to southwest. Flow in this section of the river is generally calm with relatively deep pooled areas. This is one of the widest parts of the river (approximately 600 feet) in the vicinity of RAAP.

8.4.4.2. Three settling lagoons are present at the SWMU as shown in Figure 8.1. The surface water elevation in the settling lagoons decreases from east to west during both high and low flow conditions, as indicated by the data summarized below:

	Lagoon Surface Water Elevation (feet AMSL)		
Date	Primary Lagoon	Secondary Lagoon	Tertiary Lagoon
1/19/95	1690.3	1685.9	1683.7
7/15/95	1690.1	1682.2	1679.9

The settling lagoons may act as groundwater recharge areas, however, the daily discharge of water from the drinking water settling tanks into the lagoons makes it difficult to determine this based upon relative water levels. Surface topography in the vicinity of SWMU 31 indicates a surface water flow northwestward, toward the New River. However, within the boundaries of SWMU 31, the settling lagoons capture a significant quantity of surface water runoff. As indicated in Figure 8.1 and as discussed in Section 8.1, there are numerous subsurface pipelines throughout SWMU 31.

8.4.4.3. As discussed in Section 8.1.0.4., approximately 38,670 gallons of water is discharged to the lagoons each day from the drinking water treatment plant. Average daily net precipitation results in an additional 1,800 gallons of water per day to the three lagoons. Thus, on average 40,470 gallons of water per day are added to the lagoons. Because the lagoons are at a relative steady state (i.e. neither going dry nor requiring water release through an outfall), the quantity of water input to the lagoons is equivalent to the output. Output of water is either in the form of evaporation or infiltration. The quantity of water lost to evaporation has been accounted for in the net precipitation value given above. Therefore, if these conditions are true, an average of 40,470 gallons of water per day infiltrate the substrate of the three lagoons. The groundwater table has been observed to consistently lie below the surface water elevation of the lagoons (Figure 8.4), demonstrating that infiltration of water from the lagoons is feasible. The infiltration rate has been calculated to be in the range of 1.9 inches per day. Under these conditions, the water released by the lagoons recharges the underlying aquifer and is discharged to the New River. No direct mechanical discharge of the lagoon contents to the river occurs according to facility personnel.

8.5 NATURE AND EXTENT OF CONTAMINATION

8.5.0.1. All positive results (detected compounds) for soil and aqueous samples for SWMU 31 are presented in Tables 8.5 and 8.6, respectively. The positive results and the chemicals of concern (COCs) as identified by the methods described in Section 6 are discussed below. However, the focus of the section is on the COCs identified as potential human health threats as detailed in the subsequent Risk Assessment subsections.

8.5.1 Nature of Contamination

8.5.1.1 Subsurface Soils

8.5.1.1.1. No COCs were identified in the subsurface soils at SWMU 31. Positive results were detected for eight metals in these soils, but none exceeded the established background levels for these soil types. The metals were arsenic, lead, silver, barium, beryllium, chromium, nickel, and mercury. All of these metals except mercury, silver, and arsenic, were found in every subsurface soil sample. Arsenic was found in two samples, silver was found in two samples, and mercury was found in two samples; however, not the same samples.

8.5.1.2 Groundwater

8.5.1.2.1. Positive results for nine metals were detected in the SWMU groundwater samples. Of these, selenium, barium, antimony, and beryllium were identified as COCs. Beryllium and antimony were found at concentrations considered to be a potential human

TABLE 8.5
POSITIVE RESULTS TABLE OF SWMU 31 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	31MW1A25	31MW1B35	31MW2A12	31MW2B22	31MW3A10	31MW3B20	31MW4A12	31MW4B22
METALS (ug/g)								
Arsenic				4.40 J4				
Lead	0.63 J6	7.32 J6	21.16 J1	20.86 J1	31.54 J1	40.00 J1	17.70 J1	13.96 J1
Silver		0.02 J4				0.11 J4		
Barium	28.11 J1	58.39 J1	134.90 J1	97.33 J1	134.00 J1	75.10 J1	136.78 J1	82.68 J1
Beryllium	0.94 J4	1.18 J4	1.00 J4	1.06 J4	0.95 J4	0.75 J4	1.18 J4	0.83 J4
Chromium	18.50 J6	24.10 J6	43.94	34.00	26.80	19.50	43.91	32.03
Nickel	23.62 J4	30.89 J4	13.37 J4	22.78 J4	12.60 J4	13.30 J4	20.23 J4	18.18 J4
Mercury				0.07 J4	0.18 J4			
OTHER (ug/g)								
Total Organic Carbon								

TABLE 8.5
POSITIVE RESULTS TABLE OF SWMU 31 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	31MW4C40*	31SE1	31SE3	31SE5
METALS (ug/g)				
Arsenic				
Lead	19.98 J1			
Silver				
Barium	140.53 J1			
Beryllium	1.22 J4			
Chromium	44.13			
Nickel	21.49 J4			
Mercury				
OTHER (ug/g)				
Total Organic Carbon		58557.00	77281.60	62372.90

* 31MW4C40 is a duplicate sample of 31MW4A12

TABLE 8.6
POSITIVE RESULTS TABLE OF SWMU 31 - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	31MW1	31MW1 Dissolved	31MW2	31MW2 Dissolved	31MW3	31MW3 Dissolved	31MW4	31MW4 Dissolved	31MW5*
METALS (ug/l)									
Arsenic			7.44						
Mercury					0.138		0.142		
Lead	7.58		41.8		36.2		11.3		
Selenium				5.4					
Barium	300	264	183	27	257	24.7	137	19.7	
Beryllium	5.16	3.98	6	1.63	5.24	1.86	5.26		
Chromium			97.3		89.1		31.6		
Nickel			49.9		58.4				
Antimony		65.2**							
OTHER (ug/l)									
Total Organic Carbon	2040		1320		1160				1350
Total Organic Halogens	15.4		15		25.3		15.6		33.4

* 31MW5 is a duplicate sample of 31MW3.
** The positive result for antimony was detected during the January 1995 sampling event.
All other results from July 1995.

health risk. Therefore, these metals were categorized as the risk drivers for SWMU 31 groundwater. Dissolved selenium was only found in the sample from 31MW2 at a concentration of (5.4 ug/l). Dissolved barium was detected in all four monitoring well samples, ranging from 19.7 ug/l (31MW4) to 264 ug/l (31MW1). Total beryllium was found in the samples from all wells, but dissolved beryllium concentrations were only detected in the samples from three of the wells; 31MW4 did not contain dissolved beryllium. The maximum dissolved beryllium concentration (3.98 ug/l) was in the 31MW1 sample. Dissolved antimony was only detected in 31MW1 during the January 1995 sampling event at 65.2 ug/l.

8.5.1.2.2. The other metals detected in the groundwater, but not considered to be COCs, were arsenic, mercury, lead, chromium, and nickel. However, none of these metals were found in the dissolved fraction of the metals analysis for the samples. Arsenic was only found in the 31MW2 sample. Nickel was only detected in the samples from 31MW2 and 31MW3. Mercury was only detected in the 31MW3 and 31MW4 samples. Chromium was detected in three samples, with a maximum concentration of 97.3 ug/l (31MW2).

8.5.2 Extent of Contamination

8.5.2.1 Subsurface Soils

8.5.2.1.1. Positive results for metals were found in the well borings as described above. Two soil samples were collected from each boring, one shallow and one deep. In general, no obvious pattern of metals occurrence in the samples could be observed when comparing shallow to deep samples. In four instances, metals were detected in the deep sample which were not present in the shallow sample. In one case, a metal was detected in the shallow sample which was not found in the deep sample from that boring. Overall, the metals concentrations in the three well borings along the river (in the apparent downgradient groundwater flow direction from the settling lagoons) were higher than those found in the 31MW1 well boring samples (upgradient of the lagoons). However, this was not true for all metals. The deepest samples taken which had positive detections for metals were from the same approximate elevation as the bottoms of the secondary and tertiary lagoons.

8.5.2.2 Groundwater

8.5.2.2.1. The maximum concentration of dissolved beryllium, the risk driver metal, was found in the sample from 31MW1. The maximum concentration of dissolved barium was also in the sample from 31MW1. The only detection of antimony, a risk driver metal, was also from 31MW1, in the sample collected during the January 1995 sampling event. Selenium was not detected in this well sample. This well has been shown to be hydraulically upgradient of the lagoons, which are the likely source of metals contamination at SWMU 31. The three wells along the New River, 31MW2, 31MW3, and 31MW4, are downgradient of the lagoons. The only selenium detection was in the sample from 31MW2; all three of the downgradient wells contained detectable amounts of beryllium, an identified risk driver metal. With the exception of lead, which was also detected in the upgradient well sample, all of the other detected metals were from these downgradient well samples.

8.6 CONTAMINANT FATE AND TRANSPORT

8.6.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. At SWMU 31, both the surface water and groundwater are potential migration pathways to the New River. Flooding of this area by the river is possible. Groundwater in the vicinity of SWMU 31 appears to be discharging directly to the river. Contaminants discharging to the New River would likely be significantly diluted before reaching distant downgradient receptors. The river is approximately 100 feet from the lagoon area and the groundwater velocity is estimated to be 2.31 feet/year.

8.6.0.2. The source of the relatively high metals contamination in the upgradient well (31MW1) is not clear, however, the groundwater gradient at SWMU 31 is low. The sediments in the secondary and tertiary lagoons are approximately five feet below the potentiometric surface in 31MW1. The well is approximately 140 feet from the nearest lagoon. It is possible that seasonal groundwater fluctuations allow for impact of the slightly upgradient groundwater in 31MW1. It is also possible that infiltration of the lagoon surface water is impacting the groundwater quality in the upgradient well vicinity.

8.6.0.3. Beryllium and antimony, the risk driver metals for SWMU 31 groundwater, were not detected in the surface water sample collected from the New River at the likely discharge point of SWMU 31 groundwater. Metals were found in the subsurface soils, but at levels below established background concentrations. The lagoon sediments were within TCLP regulatory limits for all parameters. Migration of metals to the river by the groundwater pathway would likely occur as dissolved ions. Movement would be at a lower rate due to dispersion and adsorption to the aquifer matrix. Metals are generally immobile in the clayey soils which are interbedded throughout the unconsolidated alluvium.

8.6.0.4. Nickel, which was one of the New River sediment COC compounds, was found in the sediment sample (NRSE6) collected just downstream of the lagoon area. However, although nickel was found at detectable levels in the SWMU 31 groundwater and soil samples, it was not found at COC levels. Chromium, barium, silver, and lead were found in both the SWMU 31 soils and the NRSE6 sediment sample. Lead, chromium, and nickel were found in the SWMU 31 groundwater and also in the NRSE6 sediment sample.

8.7 RISK ASSESSMENT

8.7.0.1. The coal ash settling lagoons are unlined and uncovered which does not limit the potential for emissions to the atmosphere and contaminants migrating from settled ash to subsurface soils and groundwater. In the future, these settling lagoons may be removed from operation and completely dismantled.

8.7.0.2. At present, future land use at this SWMU is uncertain; Power House No. 2 has been inactive since January 1993 and is currently scheduled for layaway. A potential scenario would consist of the decommissioning of the settling lagoons along with this power house. Future uses of the land in this area are expected to remain industrial.

8.7.1 Summary of Chemicals of Potential Concern

8.7.1.0.1. The chemicals considered in the risk evaluation for SWMU 31 include 4 metals, antimony, barium, beryllium and selenium in groundwater. Volatiles, semivolatiles, and explosive constituents were not included in the analytical program for groundwater at this SWMU.

8.7.1.0.2. Subsurface soil samples were collected during well drilling activities; however, the metals detected in these samples were either not detected or were below 10 feet in depth. Sediment samples were also collected from the settling lagoons, but these were collected for disposal classification purposes and the results are not quantifiable for risk assessment purposes.

8.7.1.1 Comparison to ARARs and TBCs for Groundwater

8.7.1.1.1. Groundwater in the vicinity of RAAP is not used for drinking water serving more than 25 people and therefore MCLs and MCLGs are not considered as ARARs for SWMU 31. TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995a).

8.7.2 Exposure Assessment

8.7.2.1 Potential Pathways and Receptors

8.7.2.1.1. Current exposure pathways at SWMU 31 are considered to have a low probability of completion and therefore, these scenarios were not quantified for current receptors (site workers, recreational surface water users, hunters and fishermen). Although current site workers have access to potentially contaminated sediments and surface waters from the settling lagoons, contaminant concentrations are unknown and therefore human health risk is not quantifiable. SWMU 31 is completely contained within RAAP property which effectively limits public access (recreational surface water users and fishermen) to potential contaminants. Surface soil samples were not appropriate at this SWMU because the potential contamination results from chemicals migrating from the lagoons to subsurface soils and groundwater. In addition, the current groundwater pathway is not complete as this water is not used for drinking purposes. Potential future routes of human exposure which were considered for SWMU 31 include site worker ingestion and dermal exposure to potentially contaminated groundwater. However, this exposure scenario is expected to have a low probability of completion due to present drinking water use. Future pathways for subsurface soil have a high probability of completion if this area were to undergo future development; however, contaminants detected in this medium were below the upper 95% tolerance limits established through background sampling and therefore were not included for evaluation.

8.7.2.1.2. The conceptual site model summary for SWMU 31 is presented in Figure 8.6 and includes exposure routes, potential receptors and the medium containing the potential contaminants of concern. All chemicals not eliminated by data validation and background screening were considered in the risk assessment for this SWMU.

8.7.2.2 Exposure Point Concentrations and Chronic Daily Intakes

8.7.2.2.1. Exposure point concentrations for the three metals evaluated at SWMU 31 are listed in the tables in Appendix I. These concentrations range from 0.00161 mg/L (beryllium) to 0.0432 mg/L (barium).

8.7.3 Risk Characterization

8.7.3.0.1. The carcinogenic risk and hazard index were calculated for the groundwater ingestion and dermal contact pathways. These calculations are presented in Appendix I. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

8.7.3.1 Non-carcinogenic Effects

8.7.3.1.1. Hazard indices for the hypothetical future site worker ingestion scenario exceed acceptable levels primarily due to antimony for RME receptors. The calculated hazard index is 1.03. Barium, beryllium and selenium hazard indices are at least two orders of magnitude below acceptable levels.

8.7.3.2 Carcinogenic Effects

8.7.3.2.1. The calculated cancer risks for the hypothetical future site worker ingestion and dermal contact scenario are within the USEPA target risk range primarily due to beryllium, for CT and RME receptors. The other metals evaluated do not show a cancer risk which is due to a lack of toxicity information. The CT and RME ingestion cancer risks for beryllium are 1.21×10^{-6} and 2.42×10^{-5}, respectively. Calculated dermal cancer risks for beryllium for CT and RME receptors are 5.50×10^{-7} and 1.10×10^{-5}, respectively.

Figure 8.6
Conceptual Site Model for Current and Future Exposure Pathways
SWMU 31
Radford Army Ammunition Plant
Radford, Virginia

Primary Source	Release Mechanism	Receiving Medium	Exposure Route	Current Receptors				Future Receptor
				Site Workers	Rec. Users	Hunters, Fisherman	Const. Workers	Site Workers
RAAP Activities	Surface Runoff/ Groundwater Discharge	Surface Water and Sediment	Ingestion					
			Inhalation					
			Dermal					
	Tracking Deposition	Surficial Soils	Ingestion					
			Inhalation					
			Dermal					
	Leaching/ Deposition	Subsurface Soils	Ingestion					
			Inhalation					
			Dermal					
	Uptake	Biota	Ingestion					
	Leaching	Groundwater	Ingestion					X
			Inhalation					
			Dermal					X

X = Pathways of potential concern
H = Hunter scenario

8.7.4 Uncertainty Analysis

8.7.4.0.1. Data collection/evaluation uncertainty may be relevant at SWMU 31 due to the types and numbers of samples collected. Analyses performed on the surface water and sediment samples from the settling lagoons only included total organic carbon and waste characterization. These analyses do not yield results that are usable for risk assessment purposes. Therefore, current site worker risks from potential contamination through exposure to lagoon surface water and sediments are not quantifiable and unknown.

8.7.4.0.2. Some of the metals detected at this site in groundwater are naturally occurring and in some cases, statistical methods were used to distinguish site-related from non-site-related metals. In this case, all metals detected in groundwater were retained as if they were site-related. The calculations have shown to present unacceptable risks due to these metals and this could be an overestimate due to natural metals concentration in groundwater.

8.7.4.0.3. One of the main areas of uncertainty is in exposure assessment as relates to determining future land uses at a contaminated site. The majority of the land at RAAP is commercial or industrial and used for support of the explosives manufacturing process, with few scattered residential communities located in Montgomery and Pulaski counties. Access to the SWMU 31 is restricted and therefore the use of a current residential exposure scenario is unlikely.

8.7.4.0.4. Another area of uncertainty in evaluating human health risk from SWMU 31 is toxicity assessment. Oral and dermal slope factors are not available for three of the four metals which were detected in groundwater. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

8.8 RISK SUMMARY

8.8.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for site worker receptors potentially exposed to multiple chemicals in groundwater during domestic use. The groundwater pathway calculations were summarized and are presented in

Table 8.7. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 1×10^{-4} to 1×10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 1×10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index below one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

8.8.0.2. At SWMU 31, the site worker RME receptors' total hazard index is greater than one for ingestion of groundwater. The total cancer risk value for these scenarios is within the target risk range. These values indicate a potential for noncarcinogenic and carcinogenic adverse human health effects.

8.9 SWMU 31 SUMMARY

8.9.0.1. The groundwater associated with SWMU 31 resides in the alluvial sediments overlying the limestone bedrock. The groundwater is approximately at the same elevation as the bottoms of the coal ash settling lagoons; flow direction is toward the New River. Groundwater, subsurface soils, and lagoon sediment samples were collected to characterize SWMU 31. Additionally, a surface water and sediment sample was taken from the New River at the likely discharge point of groundwater from beneath the SWMU.

8.9.0.2. Eight metals were detected in the subsurface soil samples, but concentrations were less than the established background levels for B and C horizon soils in this area. Beryllium and antimony were identified as the risk driver compounds for SWMU 31 groundwater. The lagoon sediments were only sampled for TCLP parameters. However, the previous Dames & Moore characterization sampling found beryllium at significant levels (groundwater risk driver). The lagoon sediments were within regulatory limits for all TCLP parameters. Metals found in the SWMU 31 subsurface soils and groundwater were also detected in the surface water and sediment sample collected downstream of the SWMU in the New River.

Table 8.7
Summary of Human Health Risk
SWMU 31
Radford Army Ammunition Plant

Receptor	Pathways	HI		Cancer Risk	
		CT	RME	CT	RME
Site Worker	Ingestion of Groundwater	0.26	1.05	1.21E-06	2.42E-05
	Dermal Contact with Groundwater	0.12	0.47	5.50E-07	1.10E-05
Total for Site Workers		0.38	1.52	1.76E-06	3.52E-05

8.9.0.3. In general, the highest subsurface soil metals concentrations appeared to be from the downgradient well borings. Although most of the metals detected in the groundwater were from the downgradient well samples, the maximum concentrations of two of the groundwater COC metals and the only sample with a positive detection for antimony were found in the sample from the upgradient well. However, the well is close enough to the lagoons to suggest the possibilty that seasonal groundwater level fluctuations can allow the lagoon sediments to impact the quality of the groundwater in the vicinity of this well. Additionally, the infiltration of the lagoon surface water may be adversely impacting the upgradient well.

8.9.0.4. The human health risk assessment indicated a potential for carcinogenic and noncarcinogenic adverse human health effects for SWMU 31 groundwater ingestion or dermal contact for site worker receptors.

SECTION 9

SITE CHARACTERIZATION OF SWMU 48 (OILY WASTEWATER DISPOSAL AREA)

9.1 HISTORY AND OPERATIONS

9.1.0.1. The Oily Wastewater Disposal Area (SWMU 48) is located in the RAAP Horseshoe Area, approximately 3,600 feet east of the main bridge over the New River. Plate 1 shows SWMU 48 in relation to the rest of the facility. A detailed location map of SWMU 48 is presented as Figure 9.1. The USEPA reported this unit as contiguous to SWMU 59 (Bottom Ash Pile) and SWMU 50 (Calcium Sulfate Disposal Area), with no distinction possible by visual observation (USEPA, 1987). However, based on a review of historical aerial photographs and discussions with plant personnel, it has been determined that the unit consists of two separate disposal areas. The northern (upper) disposal area is a long, narrow raised mound approximately 30 feet north of SWMU 50 and 75 feet west of SWMU 59. The southern (lower) disposal area is substantially smaller and is located approximately 30 feet south of SWMU 59 and 75 feet east of SWMU 50.

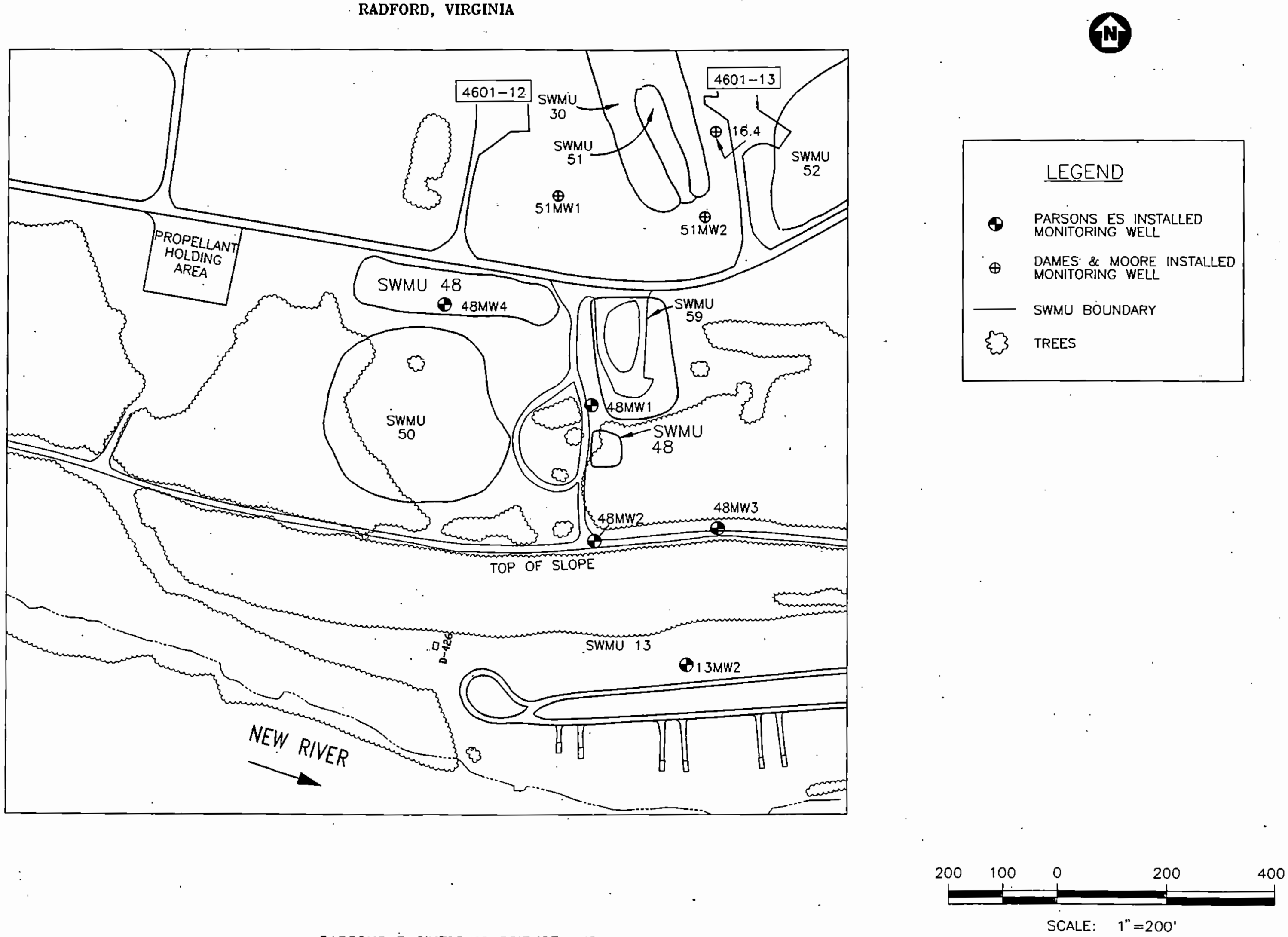
9.1.0.2. Between approximately 1975 and 1985, prior to off-post waste oil reclamation procedures, oily wastewaters removed from oil/water separators throughout RAAP were disposed at SWMU 48. Trenches the width of a bulldozer were excavated. The oily wastewater was disposed in these trenches and then the trenches were backfilled with soil and revegetated. Each new trench was dug adjacent to the previously backfilled trench. Backfill soils consisted of sandy silt or clayey silt soils obtained from either the SWMU 48 area or an onsite borrow site. It is estimated that 200,000 gallons or more of oil-contaminated wastewater was disposed of in unlined trenches at this unit.

9.2 PREVIOUS INVESTIGATIONS

9.2.0.1. This SWMU was identified in the RCRA Facility Assessment (USEPA, 1987) as having a potential for releasing contaminants into the environment and was included in the RCRA Permit for Corrective Action and Incinerator Operation (USEPA, 1989a) as

FIGURE 9.1
SWMU 48 LOCATION MAP (OILY WASTEWATER DISPOSAL AREA)

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



722843\843F9_1 10/2/95

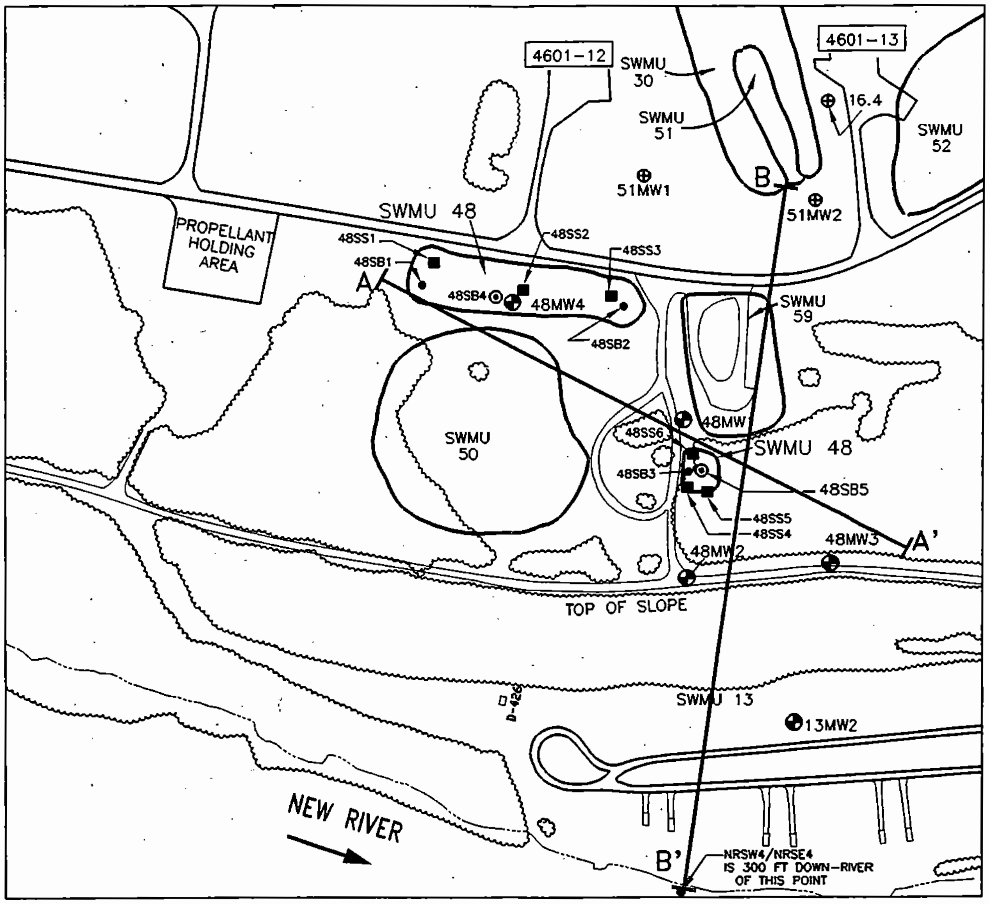
warranting investigation. Subsequently, Dames & Moore conducted a VI in August 1991. No other investigations have been undertaken at this SWMU.

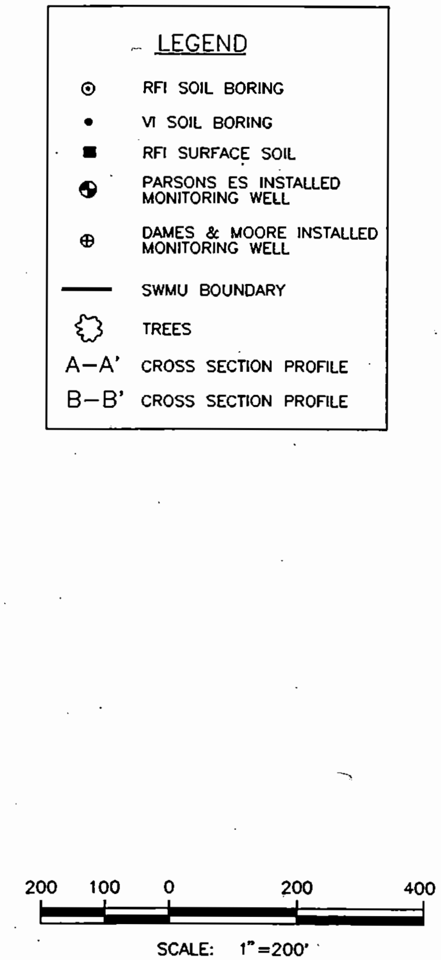
9.2.0.2. During the VI, three soil borings (48SB1, 48SB2, and 48SB3) were installed in the two disposal areas, as shown in Figure 9.2. Samples from borings 48SB1 and 48SB2 were collected at depths of 9.5 and 12 feet, respectively, in soil suspected to be contaminated at the upper disposal area. At both locations, samples were also obtained from soil below the suspected contamination at depths of 14 and 22 feet in 48SB1 and 48SB2, respectively. Only one sample was collected (from 13 feet in depth) from boring 48SB3, which was located in the smaller lower disposal area. This soil sample exhibited a fuel-like odor. The five soil samples collected were analyzed for target analyte list (TAL) metals, toxicity characteristic leaching procedure (TCLP) metals, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs). The results of the 1992 soil sampling are summarized in Table 9.1. Also included in the summary table are HBNs from the RCRA permit (USEPA, 1989a), comparison levels of soil background data calculated by Dames & Moore (1992a), and RBCs for commercial and industrial soils (USEPA, 1994).

9.2.0.3. The results of these chemical analyses indicated the presence of 19 metals. Soil sample concentrations of arsenic, beryllium and cobalt exceeded the HBN criteria, and arsenic and beryllium exceeded the RBC. The concentrations of beryllium, calcium, copper, magnesium, mercury, and sodium exceeded background uplands soil concentrations in at least one sample. Beryllium and sodium were the only inorganics to exceed background concentrations in the underlying soil in 48SB1 and 48SB2. Sodium was found in the method blanks, and beryllium was higher in the lower samples than the upper oily samples. TCLP metal concentrations did not exceed RCRA waste characterization regulatory levels. Explosives were detected in 48SB2 and were the only contaminants of concern, based on HBN criteria; they did not exceed the RBC.

9.2.0.4. VOCs were detected in soil samples collected in boring 48SB2, located in the eastern portion of the upper disposal area, and boring 48SB3, located in the lower disposal area. Ethylbenzene, toluene, and xylenes were detected in sample 48SB3 but toluene was detected at a concentration below the PQL, and the other two compounds were detected at three to five orders of magnitude below the HBN or RBC. Toluene, the only known VOC found in 48SB2, was detected at a concentration equal to the detection limit and below the PQL and was not identified as a concern. Nine VOC tentatively identified

FIGURE 9.2
SWMU 48 SAMPLE LOCATION MAP (OILY WASTEWATER DISPOSAL AREA)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA





PARSONS ENGINEERING SCIENCE, INC.

722843.84 F9.2 11/4/95

TABLE 9.1
VI DATA 1991
SUMMARY OF ANALYTICAL DATA
FOR SOIL SAMPLES COLLECTED AT SWMU 48
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 25 Feb 92 - 10 Mar 92 1.0 ft	Upland Soil Background Comparison Level*	HBN	RBC Industr Soil
TAL Inorganics (μg/g)						
Aluminum	14.1	5	2,940 B - 16,400	22,921	230,000	1,000,0C
Arsenic	30	5	LT 0.5 B - [8.19]	9	0.5	1.6
Barium	1	5	32.5 - 70.8	109	1,000	72,000
Beryllium	0.2	5	[0.767] - [4.98]	1.10	0.1	0.67
Calcium	100	5	LT 100 - 240,000	109,994	NSA	NA
Chromium	4	5	7.78 - 31.9	47.46	400	1,000,000
Cobalt	3	5	[3.01] - [25.7]	27.90	0.8	NA
Copper	7	5	3 B - 135	29.69	2,900	38,000
Iron	1,000	5	8,550 B - 41,600	39,707	NSA	NA
Lead	2	5	LT 10.5 - 154	282.84	200	NA
Magnesium	50	5	751 B - 130,000	45,931	NSA	NA
Manganese	0.275	5	168 B - 547	978	8,000	5,100
Mercury	0.1	5	LT 0.05 - 2.6	0.05	20	310
Nickel	3	5	4.91 - 30.8	37.23	1,000	20,000**
Potassium	37.5	5	327 B - 1,890	3,864	NSA	NA
Silver	4	5	LT 0.589 - 1.03	1.75	200	5,100
Sodium	150	5	315 B - 2,880	313.20	NSA	NA
Vanadium	0.775	5	8.97 - 34.3	73.89	560	7,200
Zinc	30.2	5	23.1 - 71.3	373.56	16,000	310,000
Volatiles (μg/g)						
Ethylbenzene	0.005	5	LT 0.002 - 0.047	NT	1,000	100,000
Toluene	0.005	5	LT 0.001 - 0.003	NT	1,000	200,000
Xylenes	0.005	5	LT 0.002 - 0.252 X	NT	1,000	1,000,00(
Volatile TICs (μg/g)						
1,1,3-Trimethylcyclohexane	NA	5	ND - 0.06 S	NT	NSA	NA
Total Unknown TICs	NA	5	ND - (8)0.167	NT	NSA	NA
Semivolatiles (μg/g)						
2-Methylnaphthalene	0.3	5	LT 0.049 - 29.2	NT	NSA	NA
24DNT	0.3	5	LT 0.14 - [3.22]	NT	1	2,000
26DNT	0.3	5	LT 0.085 - [1.22]	NT	1.03	1,000
bis(2-Ethylhexyl)phthalate	0.3	5	LT 0.62 - 1.02	NT	50	200
di-n-Butylphthalate	0.3	5	LT 0.061 - 2.94	NT	1,000	100,000
Fluorene	0.3	5	LT 0.033 - 8.49	NT	3,200	41,000
Naphthalene	0.3	5	LT 0.037 - 5.64	NT	1,000	41,000
Phenanthrene	0.5	5	LT 0.033 - 10	NT	40	NA
Pyrene	0.3	5	LT 0.033 - 0.318	NT	1,000	31,000

TABLE 9.1 (CONTINUED)
VI DATA 1991
SUMMARY OF ANALYTICAL DATA
FOR SOIL SAMPLES COLLECTED AT SWMU 48
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 25 Feb 92 - 10 Mar 92 1.0 ft	Upland Soil Background Comparison Level*	HBN	RBC Industi Soil
Semivolatile TICs (µg/g)						
2,6,10,14-Tetramethylpentadecane	NA	5	ND - 169 S	NT	NSA	NA
Eicosane	NA	5	ND - 96.9 S	NT	NSA	NA
Heptadecane	NA	5	ND - 218 S	NT	NSA	NA
Hexadecane	NA	5	ND - 218 S	NT	NSA	NA
Nonadecane	NA	5	ND - 145 S	NT	NSA	NA
Octadecane	NA	5	ND - 169 S	NT	NSA	NA
Tetradecane	NA	5	ND - 242 S	NT	NSA	NA
Tridecane	NA	5	ND - 218 S	NT	NSA	NA
Total Unknown TICs	NA	5	ND - (15)1,137	NT	NSA	
TCLP Metals (µg/L)						
Barium	20	5	131 - 485	NT	100,000	
Lead	10	5	LT 18.6 - 149	NT	5,000	

* Upland soil samples were collected from 5 locations at RAAP. The mean and standard deviations were calculated. Background comparison levels v selected from the upper 95 percent confidence interval of the background data set, which is equal to the mean plus two standard deviations.
** Chromium II and compounds.
*** Nickel (soluble salts).
B Analyte was detected in corresponding method blank; values are flagged if the sample concentration is less than 10 times the method blank concentra for common laboratory constituents and 5 times for all other constituents.
HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumpti consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
LT Concentration is reported as less than the certified reporting limit.
NA Not available; PQLs are not available for TICs detected in the library scans.
ND Analyte was not detected.
NSA No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
NT Not tested.
PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method.
S Results are based on an internal standard; flag is used for TICs detected in library scans.
TAL Target analyte list.
TICs Tentatively identified compounds that were detected in the GC/MS library scans.
TCLP Toxicity Characteristic Leaching Procedure
µg/g Micrograms per gram.
µg/L Micrograms per liter.
X Analyte recovery is outside of the certified range, but within acceptable limits such that a dilution is not warranted.
( ) Parentheses are used to indicate the number of unknown TICs that were detected in either the volatile or semivolatile GC/MS library scans. The numl beside the parentheses is the total concentration of all TICs detected in each respective scan.
[ ] Brackets indicate that the detected concentration exceeds the HBN or RBC.

From Dames & Moore, 1992b

compounds (TICs) were detected in sample 48SB3, but with a total concentration less than 0.23 μg/g. Two VOC TICs at a concentration less than 0.04μg/g and one VOC TIC detected at 0.009 μg/g also was found in the deeper 48SB1 sample and the shallow 48SB2 sample, respectively.

9.2.0.5. Trace concentrations of petroleum-related SVOCs were detected at the upper disposal area, but were below HBN or RBC criteria and limited to 48SB2 at a depth of 12 feet. The SVOCs and explosives were present only in the shallower of the two samples collected from each boring in the upper disposal area. Moderate levels of petroleum-related SVOC TICs were found in the soil sample 48SB3 at a depth of 13 feet.

9.2.0.6. A subsurface soil gas survey was performed on a 100-foot by 100-foot grid (50-foot intervals) around the lower disposal area. A total of eight samples, from a depth of 4 feet, were all below detection limits for pentane, methyl tertiary butyl ether (MTBE), benzene, toluene, ethylbenzene, and xylenes, except for one sample. This sample had a concentration of total volatile compounds slightly above the detection limit of 1.1 μg/L.

9.3 SUMMARY OF RFI FIELD ACTIVITIES

9.3.0.1. The RFI was undertaken at SWMU 48 to determine the source and extent of the contamination beneath the lower disposal area and to address any impact on groundwater quality, and to further assess the possible presence of oily waste and explosive contamination in the upper disposal area. To support the RFI objectives, two soil borings and four monitoring wells were installed, and six surface soil samples were collected. Locations are shown in Figure 9.2.

9.3.0.2. One soil boring was placed in the center of each of the disposal areas. Two soil samples from each boring were collected (deep and shallow). A composite soil sample from each boring was collected for disposal characterization. Three groundwater monitoring wells were placed around the lower disposal area; one was installed in the center of the upper disposal area (next to the boring). Two soil samples were collected from each of the well borings associated with the lower disposal area wells. A total of three geotechnical samples were collected from the soil or well borings, as shown in Table 4.5. Six surface soil samples were taken, three from each disposal area.

9.3.0.3. Groundwater samples were collected from all four monitoring wells. Field measurements of the groundwater were also recorded. Slug insertion and removal aquifier tests were performed on the three lower disposal area monitoring wells. All wells were surveyed for elevation and location coordinates. Additionally, the two soil borings were surveyed for elevations. All field activities were completed in January 1995, with the exception of 48MW4 (the upper disposal area well) which was installed and sampled in July 1995. The analytical parameters for all of these samples are indicated in Tables 4.3 and 4.4. A summary of these field activities is presented in Table 9.2.

9.4 ENVIRONMENTAL SETTING

9.4.1 Topography and Site Layout

9.4.1.1. SWMU 48 is situated in a cluster of SWMUs in the eastern Horseshoe Area of the facility. SWMUs in this general vicinity include SWMUs 50, 59, 51, 30, 16, 52, 27, 28, 29, and 53. SWMU 50, which is contiguous to both SWMU 48 disposal areas, is located to the south and west of the upper and lower disposal areas, respectively. Similarly, SWMU 59 is located contiguously to the east and north of the upper and lower disposal areas, respectively.

9.4.1.2. The SWMU 48 area is generally flat, sitting on a high bluff overlooking SWMU 13 and the New River. The approximate elevation of the SWMU is 1,820 feet above mean sea level. The New River is approximately 120 feet below this level. There are few buildings in the vicinity; the surroundings are undeveloped grasslands or woodlands. An asphalt road runs east-west to the north of the SWMU. A dirt road leading south from this road runs between the upper and lower disposal areas.

9.4.1.3. The upper disposal area is approximately 350 feet long by 100 feet wide. It is mounded so that it is 10-15 feet higher than the lower mound. The lower mound is approximately 75 feet long by 50 feet wide, although the exact dimensions are not known.

TABLE 9.2

SUMMARY OF SWMU 48 RFI FIELD ACTIVITIES
RADFORD ARMY AMMUNITION PLANT

SWMU	Monitoring Wells Installed and Sampled*	Soil Boring Samples	Depth (Feet Below Ground Surface)	Well-Boring Samples	Depth (Feet Below Ground Surface)	Geotechnical Samples/Depth	Surface Soil Samples	Slug Tests
48	48MW1	48SB4A11	10-11	48MW1A22	20-22	48MW2 (40-42)	48SS1	48MW1
	48MW2	48SB4B21	20-21	48MW1B54	52-54	48MW3 (10-12)	48SS2	48MW2
	48MW3	48SB4	Composite	48MW2A42	40-42	48SB5 (10-11)	48SS3	48MW3
	48MW4	48SB5A19	17-19	48MW2B46	44-46		48SS4	
		48SB5B37	35-37	48MW3A22	20-22		48SS5	
		48SB5	Composite	48MW3B32	30-32		48SS6	
							48SS8 (Dup. Of 48SS2)	

* Field measurements of pH, temperature, and conductivity were also recorded.

9.4.2 Geology

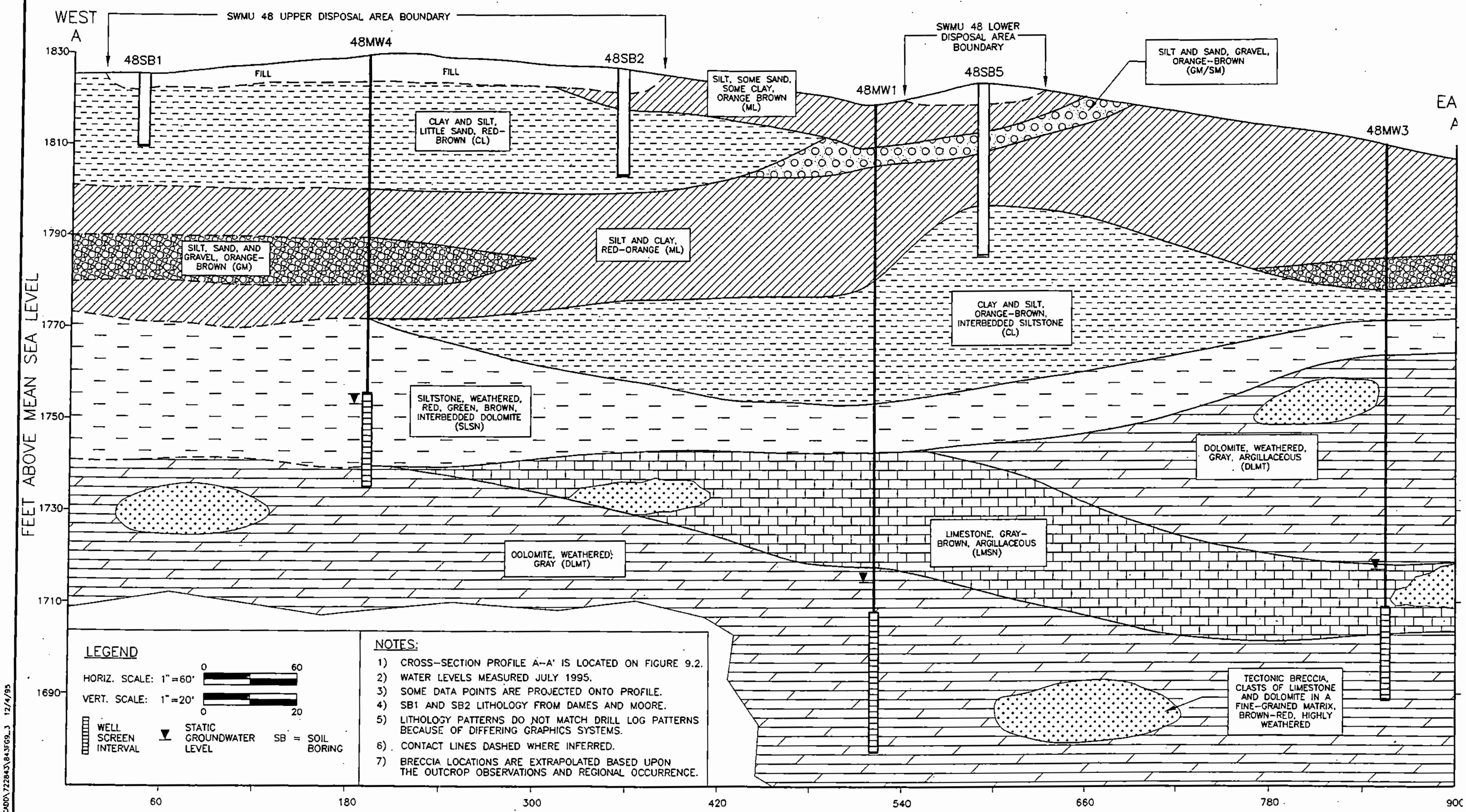
9.4.2.1. The geology of SWMU 48 was characterized by drilling four monitoring wells and two soil borings for the RFI. Additionally, data collected by Dames & Moore from three soil borings installed for the verification investigation (VI) supplemented the geological characterization. Samples were either collected continuously or at five foot intervals in each boring as described in section 4. The vertical extent of all investigatory drilling activities for the RFI was approximately 152 feet, ranging from 1830 feet above mean sea level (amsl) to 1678 feet amsl.

9.4.2.2. All geological samples were categorized under the Unified Soil Classification System (USCS) in accordance with the work plan. One sample was taken from each of three borings (48MW2, 48MW3, and 48SB5) and submitted for laboratory analysis to determine USCS designation. All other samples, including those collected for chemical analysis or general site characterization were given a USCS designation by the project geologist. This information, supplemented by the lithologic logs from the VI, as well as data from various investigations at SWMUs in the vicinity (SWMU 51, SWMU 13), was used to prepare the geologic cross sections presented as Figures 9.3 and 9.4. The cross section profile lines are shown on Figure 9.2. A west to east profile (A-A') was constructed to show the relative locations of the two disposal areas (upper and lower) of SWMU 48, while a north to south profile (B-B') shows SWMU 48 relative to the New River.

9.4.2.3. The geology of the SWMU 48 area was more complex than that of the SWMUs along the New River. The subsurface consisted of unconsolidated alluvium and residual deposits (physically and chemically weathered bedrock) overlying interbedded siltstones, limestones, and dolomites of the Elbrook Formation. The Max Meadows Breccia was evident in outcroppings along the slope leading to the river, however, it was difficult to distinguish during the drilling activities. The tectonic breccia was generally brown-red and highly weathered with many solution cavities (see Table 3.5, reference locality 1, and also Figure 3.6 which is a photograph of the breccia).

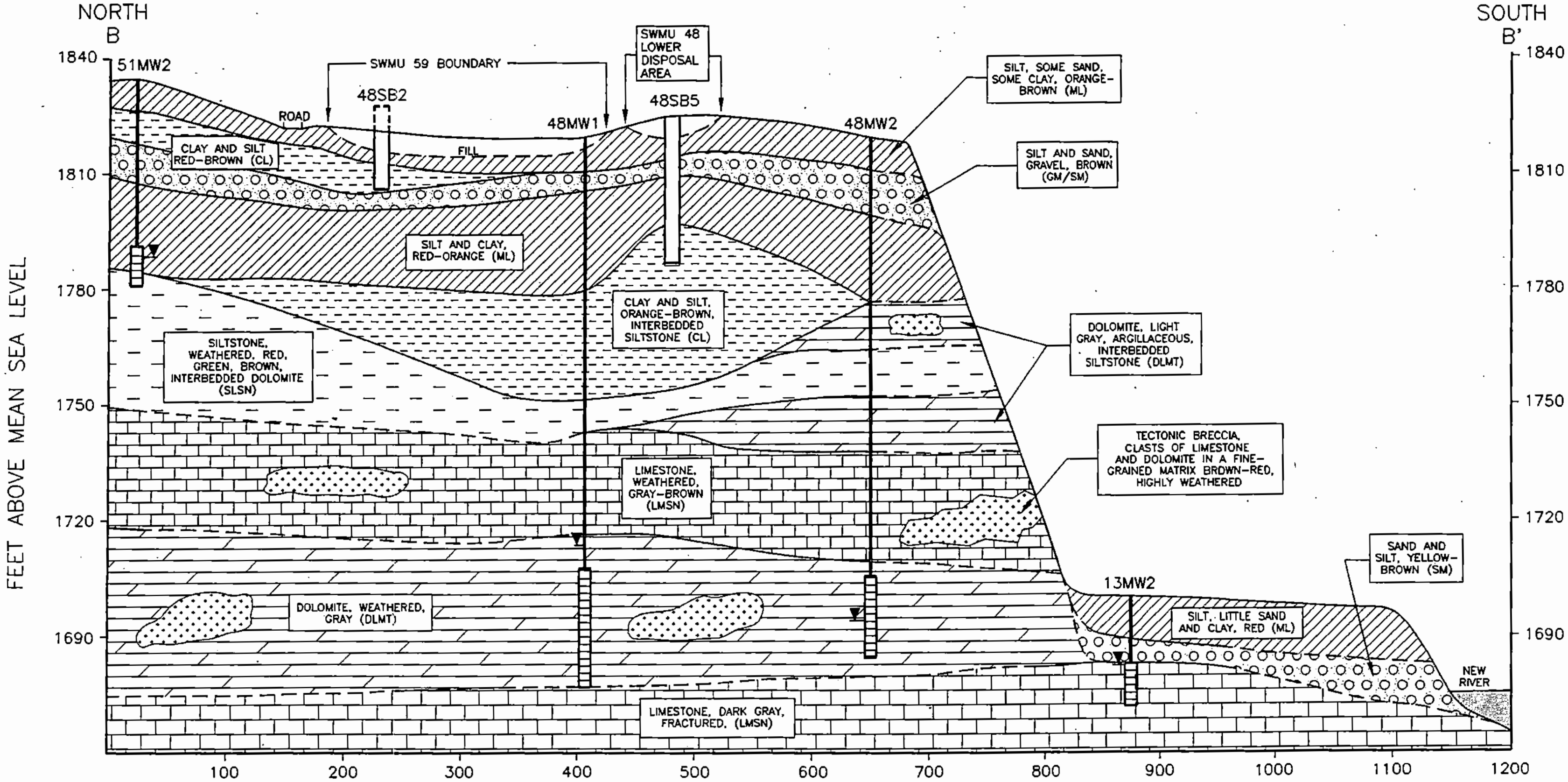
9.4.2.4. Geologic cross section A-A' (Figure 9.3) shows the shallow fill of the upper disposal area overlying a red-brown clay and silt layer (CL). Below the fill of the lower disposal area, less clay and more silt and sand was encountered in an orange-brown ML layer. The CL layer coarsened into a red-orange silt and clay (ML) at approximately 1800

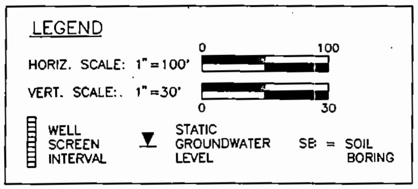
FIGURE 9.3
SWMU 48 CROSS SECTION (A-A')
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



PARSONS ENGINEERING SCIENCE INC

FIGURE 9.4
SWMU 48 CROSS SECTION (B-B')
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA





NOTES:

1) CROSS SECTION PROFILE B-B' LOCATED ON FIGURE 9.2.
2) WATER LEVELS MEASURED JULY 1995, EXCEPT FOR 13MW2 (MARCH 1992) WHICH IS PRESENTED FOR RELATIVE COMPARISON ONLY.
3) SOME DATA POINTS ARE PROJECTED ONTO PROFILE.
4) 51MW2 AND 13MW2 LITHOLOGY FROM DAMES AND MOORE.
5) LITHOLOGY PATTERNS DO NOT MATCH DRILL LOG PATTERNS BECAUSE OF DIFFERING GRAPHICS SYSTEMS.
6) CONTACT LINES DASHED WHERE INFERRED.
7) BRECCIA LOCATIONS ARE EXTRAPOLATED BASED UPON THE OUTCROP OBSERVATIONS AND REGIONAL OCCURRENCE.

J:\CADD\722843\...09_4 12/4/95

PARSONS ENGINEERING SCIENCE INC

feet amsl. The ML layer, which was interbedded with a gravel lens (GM), overlaid a weathered siltstone bedrock beneath the upper disposal area. In the eastern portion of the cross section, the orange-brown ML layer is shown grading into a silt, sand, and gravel layer (GM/SM) before becoming the red-orange silt and clay ML layer found beneath the western portion of the cross section. However, before encountering the weathered siltstone below the lower disposal area, a thick orange-brown clay and silt (CL) layer, interbedded with some siltstone, was found. This CL layer extended to approximately 1755 feet amsl before the siltstone bedrock interface was encountered. The western portion of the cross section shows the bedrock interface at approximately 1770 feet amsl. The siltstone was red-brown-green and contained interbedded dolomite.

9.4.2.5. The siltstone, which is thicker in the western portion of the study area than in the eastern end, overlies a weathered gray dolomite or gray-brown limestone. The limestone was not encountered beneath the upper disposal area (48MW4 boring). Toward the eastern end of the study area, a thick argillaceous dolomite was found above the limestone. Below the limestone, the weathered gray dolomite which was present at approximately 1740 feet amsl in the western end, was encountered at 1705 feet amsl. In general, the bedrock below the study area consisted of interbedded siltstone, limestone, and dolomite, variably hard and soft, moderately to highly weathered, containing numerous fractures, and ranging in color from red-green to brown-gray. Hydrochloric acid testing was performed to distinguish dolomite from limestone.

9.4.2.6. Geologic cross section B-B' (Figure 9.4) is a north to south depiction of strata relative to the New River. The figure generally displays the same trends of overburden and bedrock as the west to east section. However, the 48MW2 well boring shows a lens of dolomite present at a higher elevation than anywhere else in the study area. The slope leading to SWMU 13 was accessible and much of the information concerning the Max Meadows Breccia, fracturing, faulting, and jointing was gathered from studying the outcroppings along the hillside.

9.4.3 Hydrogeology

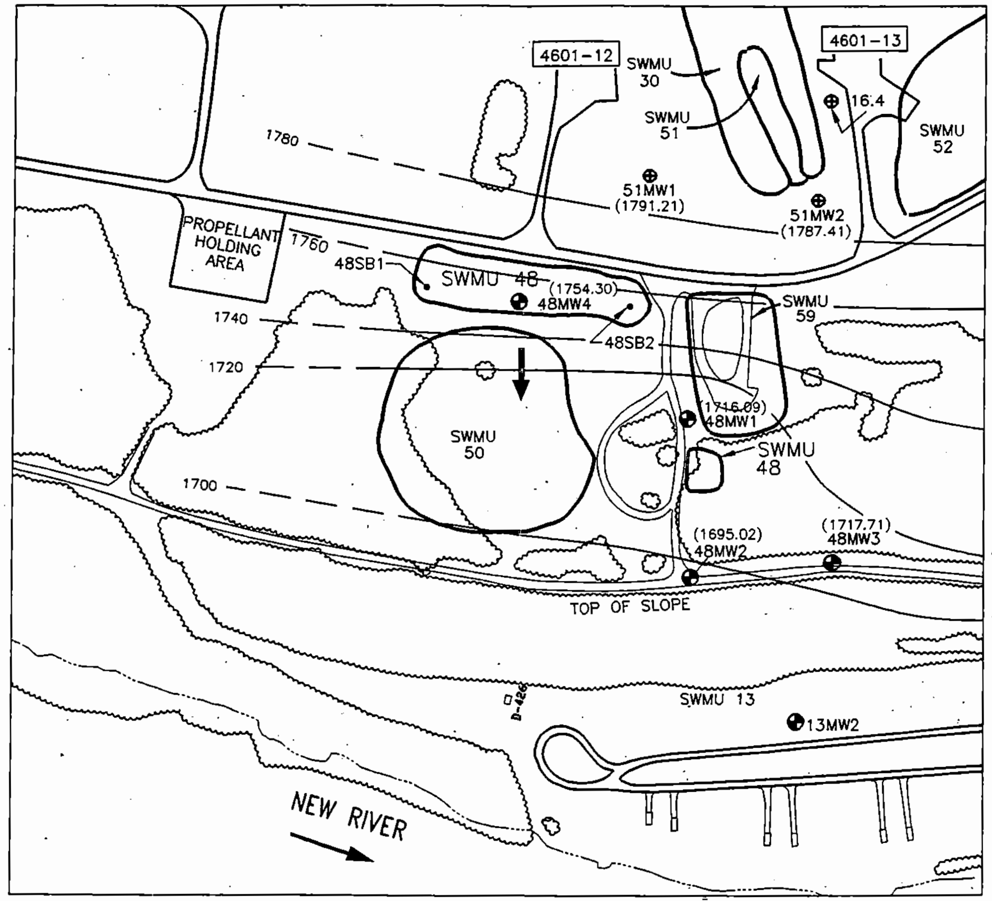
9.4.3.0.1. The four monitoring wells installed at SWMU 48 were screened in the interbedded limestone and dolomite of the Elbrook Formation. 48MW1, 48MW2, and 48MW3 were installed in January 1995; 48MW4 was installed in July 1995. The January wells were screened mostly in the dolomite, while the July well, which encountered groundwater at a higher elevation than the others, was screened mostly in a weathered siltstone interbedded with dolomite. This siltstone section was not as extensive in the vicinity of the January wells. Groundwater occurrence was unpredictable during the drilling activities. Therefore, longer well screens were used in an attempt to position the top of the screen above the stabilized groundwater level. However, due to relatively slow infiltration rates, this was not always possible. Well construction details for the monitoring wells are given in Table 4.1.

9.4.3.0.2. Groundwater occurrence and movement in the vicinity of SWMU 48 is complex. Observations and measurements of the groundwater are consistent with karst subsurface features. The following discussion of the groundwater table is presented to support observations of flow directions and flow rates. Outcroppings of limestone and dolomite along the slope immediately south of SWMU 48 contained numerous solution cavities and fractures that were oriented in various directions. Prominent exposures of the Max Meadows tectonic breccia found along the slope displayed extensive solution cavities forming a sponge-like texture indicative of intergranular dissolution. The breccia may be the site of preferential pathways for groundwater flow due to solutionization. These features demonstrate the complexity of the karst aquifer underlying SWMU 48. A fracture trace connecting several sinkholes has been identified immediately west of SWMU 48 (see Figure 3.10). In the vicinity of SWMU 48 this fracture trace is oriented north to south. A less prominent east to west fracture trace has been identified east of the SWMU. Although these features can have significant impact on groundwater occurrence and movement, within the vertical limits of the drilling activities, no major voids were encountered, and the monitoring wells apparently did not intersect these fractures.

9.4.3.0.3. The potentiometric surface (groundwater table) at SWMU 48 is shown in cross-section in Figures 9.3 and 9.4 and in plan view in Figure 9.5. Field data used to prepare Figure 9.5, photoionization detector (PID) readings of the well headspace in parts

FIGURE 9.5
SWMU 48 GROUNDWATER POTENTIOMETRIC SURFACE MAP

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



LEGEND

- SOIL BORING
- 1717.71 MONITORING WELL GROUNDWATER ELEVATION
- DAMES & MOORE INSTALLED MONITORING WELL
- SWMU BOUNDARY
- TREES
- ~1700~ POTENTIOMETRIC SURFACE (FT AMSL)
- APPARENT GROUNDWATER FLOW DIRECTION

NOTE: 1. GROUNDWATER ELEVATION MEASURED ON 7/18/95 FOR ALL WELLS EXCEPT 48MW4 (MEASURED ON 7/22/95).

2. 51MW1 AND 51MW2 ELEVATIONS MAY REPRESENT PERCHED WATER TABLE CONDITIONS.

200 100 0 200 400

SCALE: 1" =200'

722843\843F91A 12/4/95

PARSONS ENGINEERING SCIENCE, INC.

per million (ppm), pH, temperature, and conductivity of the groundwater, are summarized in Table 9.3.

9.4.3.0.4. Based on potentiometric surface maps (Figure 9.5 and Plate 2) it appears that the direction of groundwater flow is ultimately toward the New River. The hydraulic gradient as determined from Figure 9.5 is approximately 0.13 ft/ft. However, groundwater occurrence in the vicinity of SWMUs 16, 30, and 51, slightly north of the study area, is not consistent with the bedrock groundwater table found in the SWMU 48 wells. Groundwater in monitoring wells 16-4, 51MW1 and 51MW2 was encountered as much as 70 feet higher in elevation than the SWMU 48 wells. It is possible that this area represents a different groundwater zone and that a perched water table may be present in the sediments overlying the bedrock (although these wells were partially screened in rock). It is likely that this groundwater zone eventually discharges to the New River as well, but the hydraulic relationship between the shallow groundwater and the groundwater measured in the SWMU 48 wells is not completely understood.

9.4.3.1 Aquifer Testing Results

9.4.3.1.1. In order to further investigate the groundwater characteristics at SWMU 48, three falling-head (injection) and one rising-head (withdrawal) slug tests were performed on wells 48MW1 through 48MW3 in January 1995. Wells 48MW1, 48MW2 and 48MW3 intercept groundwater flow through competent limestone and dolomite bedrock. Fracture flow is likely in these wells through fractures from open conduits. The hydraulic conductivity and transmissivity data for SWMU 48 are summarized in Table 9.4; calculations and type curves from the slug test data are located in Appendix E.

9.4.3.1.2. The highest hydraulic conductivity value calculated at SWMU 48 was at well 48MW1 (4.66×10^{-5} cm/sec), and the lowest value was at well 48MW2 (1.48×10^{-6} cm/sec). The average hydraulic conductivity (2.65×10^{-5} cm/sec) calculated at SWMU 48 falls into the range of limestone and dolomite for bedrock groundwater flow (Freeze and Cherry, 1979).

TABLE 9.3
SWMU 48: GROUNDWATER FIELD DATA
RADFORD ARMY AMMUNITION PLANT

Well Name	Date	Depth to Bottom (ft)	Depth to Water (ft)	Groundwater Elevation*(ft)	PID (ppm)	pH	Temperature (degrees F)	Conductivity (us/cm)
48MW1	1-18-95	142.0	117.49	1817.79	0.9	7.88	61.1	0.97
48MW2	1-19-95	135.7	92.71	1817.62	0.3	7.81	51.2	0.96
48MW3	1-19-95	122.3	106.70	1809.96	0.2	8.49	53.3	0.98
48MW4 (1)								
48MW1	7-18-95	142.0	103.86	1716.09	0.0	6.86	NA	5.4
48MW2	7-18-95	135.7	123.86	1695.02	0.0	7.55	77.6	461
48MW3	7-21-95	122.3	94.46	1717.71	0.0	7.72	68.2	532
48MW4	7-27-95	96.1	78.30	1754.30	0.0	7.71	77.9	361

* Feet above mean sea level
(1) 48MW4 was not constructed until July 1995.
NA: No data due to instrument malfunction.

TABLE 9.4

SUMMARY OF SLUG TESTING DATA
SWMU 48 (OILY WASTEWATER DISPOSAL AREA)

RADFORD ARMY AMMUNITION PLANT

WELL	TEST DATE	SLUG TEST TYPE	HYDRAULIC CONDUCTIVITY (K) IN:		TRANSMISSIVITY (T) IN FT^2/DAY
			FT/MIN	CM/SEC	
48MW1	1-13-95	Injection/falling-head	9.18×10^{-5}	4.66×10^{-5}	6.60
48MW1	1-13-95	Withdrawal/rising-head	4.11×10^{-5}	2.08×10^{-5}	2.95
48MW2	1-13-95	Injection/falling-head	2.92×10^{-6}	1.48×10^{-6}	0.21
48MW3	1-13-95	Injection/falling-head	7.27×10^{-5}	3.71×10^{-5}	5.25
		Average for SWMU 48:	5.21×10^{-5}	2.65×10^{-5}	3.75

9.4.3.1.3. Assuming that the representative water-bearing unit at SWMU 48 is in limestone and dolomite bedrock, the horizontal groundwater flow velocity can be determined by using the Darcy Equation, as discussed in Subsection 8.4.3. The horizontal groundwater flow velocity is calculated by using the average calculated hydraulic conductivity (2.65×10^{-5} cm/sec), the hydraulic gradient (12.5 percent) as measured from Figure 9.4, and the estimated effective porosity (10 percent). The estimated porosity of 10 percent for the bedrock wells is based on a range of porosities typical for limestone and dolomite bedrock (Freeze and Cherry, 1979). By utilizing the Darcy Equation and standard equation of hydraulics ($V=Ki/n$), the estimated groundwater flow velocity at SWMU 48 was calculated to be 3.31×10^{-5} cm/sec or 34.25 ft/yr. This velocity is an estimate only since measurements of the bedrock conductivity will be variable due to irregular water-bearing fractures and solution features. Groundwater flow velocity will be significantly greater where bedrock is highly fractured and contains more solution channels. Estimated groundwater velocity values in karst environments, as found at SWMU 48, should be considered approximations.

9.4.4 Surface Water

9.4.4.1. Based on topography, surface water runoff from SWMU 48 is expected to flow approximately 700 feet southwest to the New River. The New River in this area of the facility is relatively shallow and fast-moving with numerous sections of rapids. According to RAAP utility maps, there does not appear to be any manholes, catch basins, or storm drains located in the immediate vicinity of SWMU 48.

9.5 NATURE AND EXTENT OF CONTAMINATION

9.5.0.1. A summary of all positive results (detected compounds) for soil and aqueous samples collected at SWMU 48 is presented in Tables 9.5 and 9.6, respectively. The chemicals of concern (COCs) for SWMU 48 were determined in accordance with the methods described in Section 6. The focus of this section is on the COCs identified as potential human health threats as detailed in the subsequent Risk Assessment subsections.

TABLE 9.5
POSITIVE RESULTS TABLE OF SWMU 48 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	48MW1A22	48MW1B54	48MW2A42	48MW2B46	48MW3A22	48MW3B32	48SB4A11
METALS (ug/g)							
Arsenic							
Selenium							
Lead							
Silver							
Barium							
Beryllium							
Chromium							
Nickel							
Mercury							
SEMIVOLATILES (ug/g)							
Bis(2-ethylhexyl) phthalate	8.14	7.17	1.96		3.77	2.49	3.57
Chrysene							
Di-n-butyl phthalate					2.31		
Naphthalene / Tar camphor							
N-Nitrosodiphenylamine							1.79
Phenanthrene							
Phenol			0.14				
Pyrene							
OTHER							
Total Organic Carbon (ug/g)		1353.18		39281.80		1243.78	
Total Petroleum Hydrocarbons (ug/g)							
pH							

TABLE 9.5
POSITIVE RESULTS TABLE OF SWMU 48 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	48SB4B21	48SB5A19	48SB5B37	48SS1	48SS2	48SS3	48SS4
METALS (ug/g)							
Arsenic				4.53 J4	9.78 J4		4.35 J4
Selenium							0.79 J4
Lead				5.83 J6	196.32 J6	20.88 J6	25.53 J6
Silver					0.03 J4	0.03 J4	0.03 J4
Barium				757.62 J1	100.98 J1	125.29 J1	135.39 J1
Beryllium				2.15 J4	0.91 J4	1.01 J4	
Chromium				7.07 J6	58.65 J6	28.19 J6	17.10 J6
Nickel				11.83 J4	31.17 J4	7.11 J4	7.17 J4
Mercury				1.47 J4	0.54 J4		0.59 J4
SEMIVOLATILES (ug/g)							
Bis(2-ethylhexyl) phthalate	4.35	48.60	12.33	1.99	1.60		
Chrysene				0.11			0.09
Di-n-butyl phthalate	7.26				12.27		
Naphthalene / Tar camphor		24.30					
N-Nitrosodiphenylamine	2.06						
Phenanthrene		12.15		0.36			0.37
Phenol							
Pyrene		0.97					
OTHER							
Total Organic Carbon (ug/g)	1209.19		1233.05				
Total Petroleum Hydrocarbons (ug/g)		4337.79					14.25
pH							

TABLE 9.5
POSITIVE RESULTS TABLE OF SWMU 48 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	48SS5	48SS6	48SS8*
METALS (ug/g)			
Arsenic		4.46 J4	4.76 J4
Selenium			0.78 J4
Lead	27.19 J6	16.49 J6	38.55 J6
Silver		0.03 J4	0.02 J4
Barium	66.63 J1	139.18 J1	110.72 J1
Beryllium	0.77 J4	0.87 J4	1.31 J4
Chromium	37.45 J6	18.60 J6	37.59 J6
Nickel	12.73 J4	6.75 J4	14.22 J4
Mercury	0.13 J4		0.39 J4
SEMIVOLATILES (ug/g)			
Bis(2-ethylhexyl) phthalate		1.40	1.57
Chrysene		0.08	0.09
Di-n-butyl phthalate			8.55
Naphthalene / Tar camphor			
N-Nitrosodiphenylamine			
Phenanthrene		0.33	
Phenol			
Pyrene			
OTHER			
Total Organic Carbon (ug/g)			16747.00
Total Petroleum Hydrocarbons (ug/g)	414.09		
pH			

* 48SS8 is a duplicate sample of 48SS2

TABLE 9.6
POSITIVE RESULTS TABLE OF SWMU 48 - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	48MW1	48MW1 Dissolved	48MW2	48MW2 Dissolved	48MW3	48MW3 Dissolved	48MW4	48MW4 Dissolved	48MWTB	48MWTB2
METALS (ug/l)										
Lead			9.29				12.40			
Selenium	2.72									
Barium	81.00	69.70	1070.00	816.00	70.70	69.80	299.00	295.00		
Beryllium	4.16	4.05	10.70	2.69						
Chromium			42.80							
VOLATILES (ug/l)										
1,1,1-Trichloroethane	4.10		0.98							
1,1-Dichloroethene	1.10									
1,1-Dichloroethane	2.30									
Acetone									40.00	54.00
Carbon tetrachloride			92.00		100.00					
Methylene chloride			1.10						2.90	2.60
Chloroform			6.70		30.00					
Tetrachloroethylene	1.20									
Trichloroethylene	17.00		11.00		37.00					
SEMIVOLATILES (ug/l)										
Bis(2-ethylhexyl) phthalate			12.00		23.00					
OTHER (ug/l)										
Total Hardness	445000		268000		368000					
Chemical Oxygen Demand	10000.00		41200.00		10000.00					
Total Organic Carbon			2620.00		1610.00					
Total Petroleum Hydrocarbons	143.00		480.00		247.00					
Total Organic Halogens	13.7		33.6		178					
Chloride	9300		5480		2990					

9.5.1 Nature of Contamination

9.5.1.1 Surface Soils

9.5.1.1.1. Thirteen COCs were identified in the surface soils at SWMU 48, including arsenic, barium, beryllium, chromium (as chromium III), lead, mercury, nickel, selenium, silver, and the semivolatile compounds (SVOCs), bis (2-ethyl hexyl) phalate, chrysene, di-n-butyl phthalate, and phenanthrene. Of these, arsenic and beryllium were found at concentrations considered to be a potential human health risk. Arsenic and beryllium were also considered to be the risk drivers for surface soils at SWMU 48.

9.5.1.1.2. Arsenic was detected in four of the six surface soil samples at SWMU 48, ranging in concentration from 4.35 ug/g in 48SS4 to 9.78 ug/g in 48SS2. Beryllium was detected in five surface soil samples, ranging in concentration from 0.77 ug/g in 48SS5 to 2.15 ug/g in 48SS1. Only one sample (48SS2) had a detected arsenic value greater than the background level for arsenic, which was established at 9.00 ug/g by Dames & Moore for upland soils (Table 9.1).

9.5.1.1.3. The four semivolatile compounds detected in surface soils at SWMU 48 were considered COCs. However, none of these was found at levels considered to pose a human health threat. Bis (2-ethyl hexyl) phalate was detected at three surface soil sampling locations ranging in concentration from 1.40 ug/g to 1.99 ug/g. Chrysene was detected at three surface soil sampling locations with all concentrations less than or equal to 0.11 ug/g. Di-n-butyl phthalate was only detected at 48SS2 at a concentration of 12.27 ug/g. Phenanthrene was detected at three surface soil sampling locations with all concentrations less than or equal to 0.37 ug/g.

9.5.1.1.4. Other COCs, which were not considered to be a human health threat, included barium, mercury, chromium III, nickel, selenium, lead, and silver. Barium was found in all six surface soil samples, ranging in concentration from 66.63 ug/g in 48SS5 to 757.62 ug/g in 48SS1. Mercury was detected in four surface soil samples, ranging in concentration from 0.13 ug/g in 48SS5 to 1.47 ug/g in 48SS1. Chromium III was detected in all six surface soil samples, ranging in concentration from 58.65 ug/g in 48SS2 to 7.07 ug/g in 48SS1. Nickel was found in all six surface soil samples, ranging in concentration from 6.75 ug/g in 48SS6 to 31.17 ug/g in 48SS2. However, no samples had nickel concentrations greater than the background level for this metal, which was established at 37.23 ug/g (Dames & Moore, 1992a). Selenium had a maximum detected value of 0.79 ug/g at 48SS4. Lead was detected in all samples, ranging in concentration from 5.83 ug/g in 48SS1 to 196.33 ug/g in 48SS2. Silver was found at concentrations at or below 0.03 ug/g. Although total petroleum hydrocarbons (TPH) were detected at 48SS5 at a concentration of 414.09 ug/g, these compounds were not considered COCs.

9.5.1.2 Subsurface Soils

9.5.1.2.1. Because all the subsurface soil samples from SWMU 48 were collected at depths greater than ten feet bgs, these soils were not considered in the baseline risk assessment presented in Section 6. Therefore, no COCs for the subsurface soils at SWMU 48 have been identified.

9.5.1.2.2. Seven SVOCs and total petroleum hydrocarbons were detected in the subsurface soils at SWMU 48 (Table 9.5). Bis (2-ethyl hexyl) phalate was detected in nine of ten samples, ranging in concentration from 1.96 ug/g in 48MW2A42 to 48.60 ug/g in 48SB5A19. Di-n-butyl phthalate was detected in only two samples, at 2.31 ug/g in 48MW3A22 and at 7.26 ug/g in 48SB4B21. Naphthalene was only detected in 48SB5A19 at 24.30 ug/g. N-nitrosodiphenylamine was detected in only two samples, at 1.79 ug/g in 48SB4A11 and at 2.06 ug/g in 48SB4B21. Phenanthrene was only detected in 48SB5A19 at 12.15 ug/g. Phenol was only detected in 48MW2A42 at 0.14 ug/g. Pyrene was only detected in 48SB5A19 at 0.97 ug/g. TPH was only detected in 48SB5A19 at 4337.79 ug/g. A level of 100 ug/g has been established by the State of Virginia for TPH in soils as a general guideline; TPH action levels are established in accordance with identified risk.

9.5.1.3 Groundwater

9.5.1.3.1. Eleven COCs were identified in the groundwater in SWMU 48. They included barium, beryllium, the SVOC bis(2-ethyl hexyl)phthalate, and the volatile compounds (VOCs) 1,1,1-trichloroerthane, 1,1-dichloroethane, 1,1-dichloroethene, carbon tetrachloride, methylene chloride, chloroform, tetrachloroethylene, and trichloroethylene. Of these compounds, beryllium, 1,1-dichloroethene, and carbon tetrachloride were found at concentrations considered to be a potential human health risk. Beryllium and carbon tetrachloride were considered to be the risk drivers for groundwater at SWMU 48.

9.5.1.3.2. Beryllium was detected in two well samples. Dissolved beryllium was detected at concentrations of 4.05 ug/l in 48MW1 and 2.69 ug/l in 48MW2. Carbon tetrachloride was found at relatively high concentrations at two wells, but was not detected in the other two wells at SWMU 48. This compound was detected at a concentration of 92 ug/l in 48MW2 and at 100 ug/l in 48MW3. 1,1-dichloroethene was only detected in 48MW1 at 1.10 ug/l.

9.5.1.3.3. Other COCs in groundwater at SWMU 48 that were not considered to be a potential human health risk include, barium, 1,1,1-trichloroethane, 1,1-dichloroethane, chloroform, methylene chloride, tetrachloroethene, and trichloroethylene. Of these compounds, 1,1-dichloroethane and tetrachloroethylene were only detected in 48MW1 at concentrations less than 2.5 ug/l (Table 9.6). Methylene chloride was only detected in 48MW2, at a concentration of 1.10 ug/l. Trichloroethylene was detected in three of the four well samples at SWMU 48, ranging in concentration from 11 ug/l in 48MW2 to 37 ug/l in 48MW3. 1,1,1-trichloroethane was detected in two wells, at a concentration of 4.10 ug/l in 48MW1 and at 0.98 ug/l in 48MW2. Chloroform was detected in two wells at SWMU 48. Chloroform was detected at a concentration of 6.70 ug/l in 48MW2 and at 30.00 ug/l in 48MW3. Barium was detected in all four well samples. The maximum dissolved concentration was 816 ug/l, found in the sample from 48MW2. In the remaining samples dissolved barium concentrations ranged from 69.70 ug/l in 48MW1 to 295 ug/l in 48MW4. Bis(2-ethyl hexyl)phthalate was detected in 48MW2 and 48MW3. Positive results for groundwater samples at SWMU 48 that were not COCs include the unfiltered (total) metals lead, selenium, and chromium.

9.5.2 Extent of Contamination

9.5.2.1 Surface Soils

9.5.2.1.1. All six surface soil samples at SWMU 48 were collected within the top 0.5 feet of soil. The maximum concentration of arsenic in the surface soils at SWMU 48 (9.78 ug/g) was found in 48SS2. This sample was collected at the center of the mound which makes up the upper disposal area. Approximately 150 feet west of that sampling location, within the upper disposal area, the next highest concentration of arsenic was found, 4.53 ug/g in 48SS1. The other two sampling locations at which arsenic was detected were 48SS4 and 48SS6, both located along the perimeter of the lower disposal area at SWMU 48. These samples had detected arsenic concentrations of slightly less than 4.5 ug/g.

9.5.2.1.2. Several of the COC metals for surface soils at SWMU 48 (barium, beryllium, and mercury) were detected at their maximum concentrations in sample 48SS1. The concentration of these three metals in 48SS1 were at least twice as high as the concentrations detected at any of the other surface soil sampling localities. Barium was detected in all the surface samples collected. The concentration of barium at 48SS1 was 757.62 ug/g; it ranged in concentration from 66.63 ug/g to 139.18 ug/g for all other sampling locations. Beryllium, the other risk driver metal, was detected in all the surface samples collected except 48SS4. The concentration of beryllium at 48SS1 was 2.15 ug/g, while it was detected at a concentration of approximately 1.00 ug/g or less for all other sampling locations. Mercury was detected in all the surface samples collected except 48SS3 and 48SS6. The concentration of mercury at 48SS1 was 1.47 ug/g; it ranged in concentration from 0.13 ug/g to 0.59 ug/g for all other sampling locations.

9.5.2.1.3. In general, all of the metals of primary concern were detected at 48SS1 and 48SS2, located in the western and central regions of the upper disposal area,respectively. The most significant results were in the samples from 48SS1. Neither arsenic or mercury was detected in the surface soil sample from the eastern region of the upper disposal area (48SS3). The surface soil samples from the lower disposal area (48SS4, 48SS5, and 48SS6) showed less contamination than those from the upper area. Sample 48SS4 displayed the most significant contamination in the lower area, having relatively high levels of arsenic, barium and mercury.

9.5.2.2 Subsurface Soils

9.5.2.2.1. Seven SVOCs and total petroleum hydrocarbons were detected in the subsurface soils at SWMU 48. Of these eight compounds, four were only detected in sample 48SB5A19. These compounds include naphthalene, phenanthrene, pyrene, and total petroleum hydrocarbons. Bis (2-ethyl hexyl) phalate was detected in 9 of the 10 subsurface soil samples at SWMU 48; however, the maximum concentration (48.60 ug/g) was also observed in 48SB5A19. The next two highest detected concentrations of bis (2-ethyl hexyl) phalate (8.14 ug/g and 7.17 ug/g) were observed in the two samples from soil boring 48MW1, 48MW1A22 and 48MW1B54, respectively. N-nitrosodiphenylamine was detected at the maximum concentration (2.06 ug/g) in 48SB4B21. The only sample with a detection of di-n-butyl phthalate was also 48SB4B21.

9.5.2.2.2. Generally, the highest concentration of subsurface soil contamination was observed in the shallow (17-19 feet bgs) sample from 48SB5, located in the lower disposal area. The deeper sample (19-21 feet bgs) from 48SB4, located in the upper disposal area, displayed next highest concentration of subsurface soil contamination. Breakdown products from the oily wastewater dumped at SWMU 48 may be accumulating at approximately 17-21 feet bgs across the SWMU.

9.5.2.3 Groundwater

9.5.2.3.1. The maximum concentration of dissolved beryllium was found at 48MW1 (4.05 ug/l). The only other sample with detected dissolved beryllium was 48MW2 (2.69 ug/l). Carbon tetrachloride was observed at relatively high concentrations at two wells, but was not detected in the other two wells at SWMU 48. This compound was detected at a concentration of 92 ug/l in 48MW2 and at 100 ug/l in 48MW3. The maximum dissolved concentration of barium was 816 ug/l, found in the sample from 48MW2. The next highest concentration of barium was 295 ug/l, in 48MW4. This was the only COC detected in 48MW4. Barium was also detected at 48MW1 and 48MW3 at a concentration of about 70 ug/l.

9.5.2.3.2. Generally, the most significant groundwater contamination at SWMU 48 was found in 48MW2, which can be considered to be downgradient from both the upper and lower disposal areas. Significant VOC contamination was also apparent in 48MW3. However, based on the potentiometric surface map for this site (Figure 9.4) it does not appear that groundwater contamination from SWMU 48 would migrate in the direction of 48MW3.

9.5.2.3.3. It is possible that the contaminants detected in SWMU 48 groundwater originated from some other upgradient source. Numerous other SWMUs, which are not part of this investigation, are in the vicinity of SWMU 48. However, the source of the VOC contamination in groundwater at SWMU 48 has not been determined. Carbon tetrachloride and chloroform were not detected in monitoring wells upgradient from SWMU 48 during previous investigations. Furthermore, these compounds are not components of oily wastewater. Carbon tetrachloride and chloroform were detected in downgradient monitoring wells at SWMU 13 during previous investigations (Dames & Moore, 1992a), at concentrations lower than those observed at SWMU 48. Carbon tetrachloride was detected at

10.5 ug/l in 13MW3. Chloroform was detected at 1.33 ug/l in 13MW3 and at 0.605 ug/l in 13MW4. The highest concentration of beryllium and the second highest concentration of barium in groundwater at SWMU 48 were observed in the upgradient monitoring wells.

9.6 CONTAMINANT FATE AND TRANSPORT

9.6.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. At SWMU 48, both surface water and groundwater are potential migration pathways to the New River. The areas of surface soil contamination are susceptible to transport by surface water runoff. Although groundwater movement is controlled by karst subsurface features, and is therefore unpredictable, direct discharge to the New River is likely. However, the exact location where SWMU 48 groundwater might enter the New River is uncertain. The estimated groundwater flow velocity at SWMU 48 is 34.25 feet/year.

9.6.0.2. Metals of concern identified at SWMU 48 (arsenic and beryllium) are generally immobile in the clay-rich residuum underlying this SWMU. A low solubility is expected for arsenic due to coprecipitation of the arsenate anion with iron species in the soil. Surface water runoff could be effective in mobilizing metals present in the surface soils at SWMU 48, either as dissolved ions or absorbed on suspended sediment. Dissolved metals present in groundwater are mobile.

9.6.0.3. The VOC of concern at SWMU 48 (carbon tetrachloride) tends to have a low residence time in surface soil and surface water environments. VOCs can be persistent in groundwater. However, there is evidence that non-chlorinated volatile organic compounds may degrade rapidly in the vadose zone above groundwater plumes. Carbon tetrachloride has not been detected upgradient from SWMU 48, but these compounds have been detected in groundwater sampled downgradient from this area, at SWMU 13 (Dames & Moore, 1992a). This suggests a hydrologic connection between these two areas.

9.6.0.4. The sample collected from the New River near the likely discharge point of groundwater (in the vicinity of SWMU 13) contained barium in the surface water, and numerous metals and some SVOCs in the associated sediment sample. However, many of these same compounds were also found in the SWMU 13 samples. It is not possible to differentiate between possible impacts to the quality of the New River from SWMU 48 and SWMU 13 where the contaminants are similar. Surface water and sediment sampling results for the New River are discussed in Section 12.

9.7 RISK ASSESSMENT

9.7.0.1. The Oily Wastewater Disposal Area (SWMU 48) was used to dispose of wastewater from oil/water separators into trenches that were dug on site. This site has been inactive since 1985; currently, site workers can be exposed to surface soils at the facility. Future land use at this SWMU is uncertain; this area may be used for further commercial development. Consequently, groundwater and surface soils are potential sources of concern at SWMU 48.

9.7.1 Summary of Chemicals of Potential Concern

9.7.1.0.1 . The chemicals considered in the risk evaluation for groundwater at SWMU 48 include 2 metals (barium and beryllium), one semivolatile (bis(2ethylhexyl)phthalate) and 8 volatiles (1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-dichloroethylene, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, and trichloroethylene).

9.7.1.0.2 . The chemicals considered in the risk evaluation for surface soils at SWMU 48 include 9 metals (arsenic, barium, beryllium, chromium III, lead, mercury, nickel, selenium, and silver), and 4 semivolatiles (bis (2-ethylhexyl) phthalate, di-n-butyl phthalate, chrysene, and phenanthrene).

9.7.1.1 Comparison to ARARs and TBCs for Groundwater and Soils

9.7.1.1.1. Groundwater in the vicinity of RAAP is not used for drinking water serving more than 25 people and therefore MCLs and MCLGs are not considered as ARARs for SWMU 48. In addition, there are no federal or Commonwealth of Virginia standards relating chemical concentrations in soils to toxic effects on vegetation or wildlife. TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995a).

9.7.2 Exposure Assessment

9.7.2.1 Potential Pathways and Receptors

9.7.2.1.1. Current exposure pathways considered at SWMU 48 include site workers, construction workers and hunters. The remaining potential receptors have a low probability of completion and therefore, are not quantified for current receptors (area residents and recreational users). SWMU 48 is completely contained within RAAP property which effectively limits public access to potential contaminants. Subsurface soil samples were taken at this SWMU, but all samples were taken at depths that are not appropriate for inclusion in this risk evaluation (>10 feet below ground surface). In addition, the current groundwater pathway is not complete as this water is not used for drinking purposes. Potential future routes of human exposure which were considered for SWMU 48 include site worker ingestion, inhalation and dermal exposure to potentially contaminated groundwater. However, this exposure scenario is expected to have a low probability of completion due to present drinking water use.

9.7.2.1.2. The conceptual site model summary for SWMU 48 is presented in Figure 9.6 and includes exposure routes, potential receptors and the medium containing the potential contaminants of concern. All chemicals not eliminated by data validation were considered in the risk assessment for this SWMU.

9.7.2.2 Exposure Point Concentrations and Chronic Daily Intakes

9.7.2.2.1. Exposure point concentrations for the chemicals of concern evaluated for SWMU 48 are listed in the tables in Appendix I. These concentrations range from 0.000609 mg/L (methylene chloride, 1,1-dichloroethylene) to .185 mg/L (barium) in groundwater and .0645 mg/kg (silver) to 758 mg/kg (barium) in surface soils.

9.7.3 Risk Characterization

9.7.3.0.1. The carcinogenic risk and hazard index were calculated for the groundwater ingestion and dermal contact pathways. These calculations are presented in Appendix I. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

Figure 9.6
Conceptual Site Model for Current and Future Exposure Pathways
SWMU 48
Radford Army Ammunition Plant
Radford, Virginia

Primary Source	Release Mechanism	Receiving Medium	Exposure Route	Current Receptors: Site Workers	Current Receptors: Rec. Users	Current Receptors: Hunters, Fisherman	Current Receptors: Const. Workers	Future Receptor: Site Workers
RAAP Activities	Surface Runoff/ Groundwater Discharge	Surface Water and Sediment	Ingestion					
			Inhalation					
			Dermal					
	Tracking Deposition	Surficial Soils	Ingestion	X		X(H)	X	
			Inhalation	X			X	
			Dermal	X		X(H)	X	
	Leaching/ Deposition	Subsurface Soils	Ingestion					
			Inhalation					
			Dermal					
	Uptake	Biota	Ingestion					
	Leaching	Groundwater	Ingestion					X
			Inhalation					
			Dermal					X

X = Pathways of potential concern
H = Hunter scenario

9.7.3.1 Non-carcinogenic Effects

9.7.3.1.1. The calculated hazard indices for the current site worker exposure to surface soils through ingestion and dermal contact exposure scenarios do not exceed acceptable levels. Hazard indices for this receptor are generally one to two orders of magnitude below acceptable levels.

9.7.3.1.2 . Scenarios for surface soil exposure to construction workers and hunters were analyzed at SWMU 48. The calculated hazard indices for construction worker exposure to surface soils through ingestion, dermal contact and inhalation are all below acceptable levels. The construction worker dermal contact exposure scenario calculations showed the highest hazard indices. However, these calculations were one order of magnitude below acceptable levels.

9.7.3.1.3 . The calculated hazard indices for the current scenario of hunter exposure to surface soils through ingestion and dermal contact at SWMU 48 do not exceed acceptable levels for CT and RME receptors. The totals for this site are at least two orders of magnitude below acceptable levels.

9.7.3.1.4 . The calculated hazard indices for the hypothetical future scenario of site worker exposure to groundwater through ingestion and dermal contact while showering at SWMU 48 do not exceed acceptable levels for CT and RME receptors. Calculated hazard indices are at least one order of magnitude below acceptable levels. The inhalation of volatiles hazard index exceeds one for the site worker RME receptor, due to trichloroethene (HI = 3.38).

9.7.3.2 Carcinogenic Effects

9.7.3.2.1 . The calculated cancer risks for the current site worker exposure to surface soil through dermal contact scenario are above USEPA target risk range primarily due to arsenic and beryllium, for CT and RME receptors. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are below the USEPA target range for cancer risk. Beryllium was calculated to have the highest cancer risk for the exposure through dermal contact scenario with calculations of 1.02×10^{-5} for CT and 1.32×10^{-4} for RME. Arsenic also shows cancer risk within the target risk range with calculations of 3.06 x 10^{-6} for RME. The cancer risk for RME current site worker ingestion is also within the USEPA target range for cancer risk.

9.7.3.2.2 . The calculated cancer risks for the hunter exposure to surface soil through dermal contact scenario are within USEPA target risk range primarily due to beryllium, for CT and RME receptors. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are below the USEPA target range for cancer risk. Beryllium was calculated to have the highest cancer risk for the exposure through dermal contact scenario with calculations of 2.30 x 10^{-6} for CT and 2.50 x 10^{-5} for RME. The calculated cancer risks for the hypothetical future hunter exposure to surface soil through the ingestion of surface soil scenario are within the USEPA target risk range for RME receptors, primarily due to beryllium.

9.7.3.2.3 . The calculated cancer risks for the hypothetical future site worker exposure to groundwater through ingestion are within the USEPA target risk range, for CT and RME receptors, primarily due to beryllium. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are below the USEPA target range for cancer risk. Beryllium was calculated to have the highest cancer risk for the exposure through ingestion exposure scenario with calculations of 1.02 x 10^{-6} for CT and 2.04 x 10^{-5} for RME. Carbon tetrachloride also has cancer risks within the target risk range for ingestion with calculations of 3.15 x 10^{-6} for RME. The calculated cancer risks for the hypothetical future site worker exposure to groundwater through dermal contact exposure scenario are within USEPA target risk range primarily due to high levels of beryllium, for RME receptors. The cancer risks for beryllium for this exposure scenario were 9.32 x 10^{-6} for RME.

9.7.3.2.4 The calculated cancer risks for the construction worker exposure scenario to surface soil through ingestion and dermal contact are within the USEPA target risk range, for CT and RME receptors, with the exception of the CT receptor for the ingestion exposure scenario. This is primarily due to beryllium. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are below the USEPA target range for cancer risk. The cancer risk for beryllium for the dermal contact exposure scenario was 2.04 x 10^{-6} for CT and 1.06 x 10^{-5} for RME. Arsenic and beryllium exhibit cancer risks within the target risk range for the ingestion exposure scenario for RME receptors, with cancer risks being 1.97 x 10^{-6} and 1.24 x 10^{-6}, respectively.

9.7.4 Uncertainty Analysis

9.7.4.0.1. Data collection/evaluation uncertainty may be relevant at SWMU 48 due to the types and numbers of samples collected. Many metals detected at this site in groundwater and surface soils are naturally occurring and no analysis was accomplished to differentiate between site-related and non-site-related concentrations. In this case, all metals detected in groundwater and surface soils were retained as if they were site-related. Some calculations have shown to present unacceptable risks due to these metals and this could be an overestimate due to natural metals concentration in groundwater and surface soils.

9.7.4.0.2. One of the main areas of uncertainty is in exposure assessment as relates to determining future land uses at a contaminated site. The majority of the land at RAAP is classified as commercial or industrial to support the explosives manufacturing process, with few scattered residential communities located in Montgomery and Pulaski counties. Access to SWMU 48 is restricted and therefore a current residential exposure scenario is unlikely. A future residential exposure scenario is also unlikely; therefore, future land use was assumed to remain industrial.

9.7.4.0.3. Another area of uncertainty in evaluating human health risk from SWMU 48 is toxicity assessment. Oral and dermal slope factors are not available for seven of the nine metals which were detected in groundwater, including lead. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

9.7.4.0.4. Modeled concentrations used in exposure assessment also have a certain degree of uncertainty. The inhalation of volatiles from groundwater while showering exposure scenario uses modeled concentrations of airborne volatiles to assess human health risk. These modeled concentrations use assumptions which are based on the physical and chemical properties of trichloroethylene. Therefore, the model is more precise when showing risks due to the presence of trichloroethylene in groundwater, and less precise for other volatile chemicals detected in groundwater. This may tend to over- or underestimate risk.

9.8 RISK SUMMARY

9.8.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for site worker receptors potentially exposed to multiple chemicals in groundwater during domestic use. The groundwater pathway calculations were summarized and are presented in Table 9.7. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 1×10^{-4} to 1×10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 1×10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index below one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

9.8.0.2. At SWMU 48, construction worker and hunter cancer risks are within the target risk range. The hazard index for the site worker is greater than one for RME receptors. The site worker RME receptor is also greater than 1×10^{-4}. These values indicate a potential for noncarcinogenic and carcinogenic adverse human health effects for the exposure scenarios discussed above at SWMU 48.

9.9 SWMU 48 SUMMARY

9.9.0.1. The groundwater associated with SWMU 48 is contained within the limestone and dolomite of the karst aquifer underlying this area. Although the groundwater flow direction appears to be toward the New River, groundwater movement and occurrence has not been completely defined in this vicinity. Groundwater, surface soils, and subsurface soils were collected to characterize this SWMU. Additionally, a surface water and sediment sample were collected from the New River at the likely discharge point of groundwater from SWMU 48.

9.9.0.2. Arsenic and beryllium were considered to be the risk drivers for surface soils at SWMU 48. Seven SVOCs and total petroleum hydrocarbons were detected in the subsurface soils at SWMU 48. Subsurface soils were not considered in the risk assessment, however, because the samples were collected at depths greater than 10 feet bgs. Beryllium and carbon tetrachloride were identified as the risk drivers for groundwater at SWMU 48. Carbon tetrachloride was not detected in monitoring wells upgradient from SWMU 48 during previous investigations. However, this compound was detected, at concentrations lower than

Table 9.7
Summary of Human Health Risk
SWMU 48
Radford Army Ammunition Plant

Receptor	Pathways	HI		Cancer Risk	
		CT	RME	CT	RME
Site Worker	Ingestion of Groundwater	0.03	0.13	1.27E-06	2.54E-05
	Dermal Contact with Groundwater	0	0	4.70E-07	9.44E-06
	Inhalation of Volatiles from Groundw	0.69	3.38	8.61E-08	2.10E-06
	Ingestion of Surface Soil	0.01	0.05	4.18E-07	8.36E-06
	Dermal Contact with Surface Soil	0.13	0.33	1.04E-05	1.35E-04
	Inhalation of Surface Soil Volatiles	0	0	5.32E-17	8.01E-16
	Inhalation of Surface Soil Particulates	0	0	6.98E-15	1.05E-13
Total for Site Worker		0.86	3.89	1.26E-05	1.80E-04
Hunter	Ingestion of Surface Soil	0	0.01	1.50E-07	2.61E-06
	Dermal Contact with Surface Soil	0.02	0.03	2.35E-06	2.56E-05
Total for Hunter		0.02	0.04	2.50E-06	2.82E-05
Construction Worker	Ingestion of Surface Soil	0.05	0.24	1.67E-07	3.21E-06
	Dermal Contact with Surface Soil	0.26	0.33	2.09E-06	1.08E-05
	Inhalation of Surface Soil Volatiles	0	0	2.56E-17	1.79E-16
	Inhalation of Surface Soil Particulates	0	0	3.36E-15	2.35E-14
Total for Construction Workers		0.31	0.57	2.26E-06	1.40E-05

those observed at SWMU 48, in downgradient monitoring wells at SWMU 13 during previous investigations.

9.9.0.3. In general, the greatest surface soil metals concentrations were observed in the western and central regions of the upper disposal area. The highest concentration of subsurface soil contamination was observed in the 17-19 foot interval in both the upper and lower disposal areas. The highest concentrations of VOCs and metals were observed in the downgradient monitoring well sample and in the side-gradient monitoring well sample at SWMU 48. However, the highest beryllium concentration and second highest barium concentration was observed in the upgradient wells. This suggests the possibility of an upgradient source impacting groundwater quality at SWMU 48. SWMU 48 is situated in a cluster of SWMUs within the Horseshoe Area.

9.9.0.4. The human health risk assessment indicated a potential for noncarcinogenic and carcinogenic adverse human health effects for ingestion, dermal contact or volatile inhalation of groundwater for site worker receptors. A potential for carcinogenic adverse human health effects for dermal contact or ingestion of surface soil was also identified for site worker, hunters and construction worker receptors at SWMU 48.

SECTION 10

SITE CHARACTERIZATION OF SWMU 54 (PROPELLANT ASH DISPOSAL AREA)

10.1 HISTORY AND OPERATIONS

10.1.0.1. The Propellant Ash Disposal Area (SWMU 54) is located in the easternmost section of the Horseshoe Area, just outside Gate 19-D of the RAAP fence. Plate 1 shows SWMU 54 in relation to the rest of the facility. A detailed location map of SWMU 54 is presented as Figure 10.1. The total area of the unit is estimated to be less than 1 acre. Ash from propellant burning operations at the Waste Propellant Burning Ground (SWMU 13) was reportedly disposed of at this unit during the late 1970s, prior to startup of the Hazardous Waste Landfill (SWMU 16) in 1980. The quantity of ash disposed of in this unit is estimated to be 10 tons (USATHAMA, 1976). According to plant personnel, disposal occurred on the surface with no routine disposal in pits or trenches. Ash residue is visible where surface soils have been disturbed.

10.1.0.2. The propellant ash is the residue of the burning of waste explosives, propellants, and laboratory wastes (propellant and explosive residues, samples, and analytical residues). A sample of the ash disposed of in the Hazardous Waste Landfill was analyzed for RCRA metals (EP toxicity leachate analysis). Results indicated that the ash content exceeded the Virginia maximum allowable TCLP concentration for lead (51 mg/l, compared to the maximum allowable concentration of 5 mg/l) (USEPA, 1987). It is likely that ash disposed of in SWMU 54 exhibits similar characteristics.

10.2 PREVIOUS INVESTIGATIONS

10.2.0.2. Dames & Moore conducted a VI at this SWMU in August 1991. During this investigation, three wells were installed, one upgradient (54MW1) and two downgradient (54MW2 and 54MW3) of the disposal area, to evaluate whether groundwater quality has been impacted by ash disposed in the unit. Locations for the three wells are shown in Figure 10.1. Initially, the upgradient well was 54MW1A. However, it was replaced by 54MW1

10-2

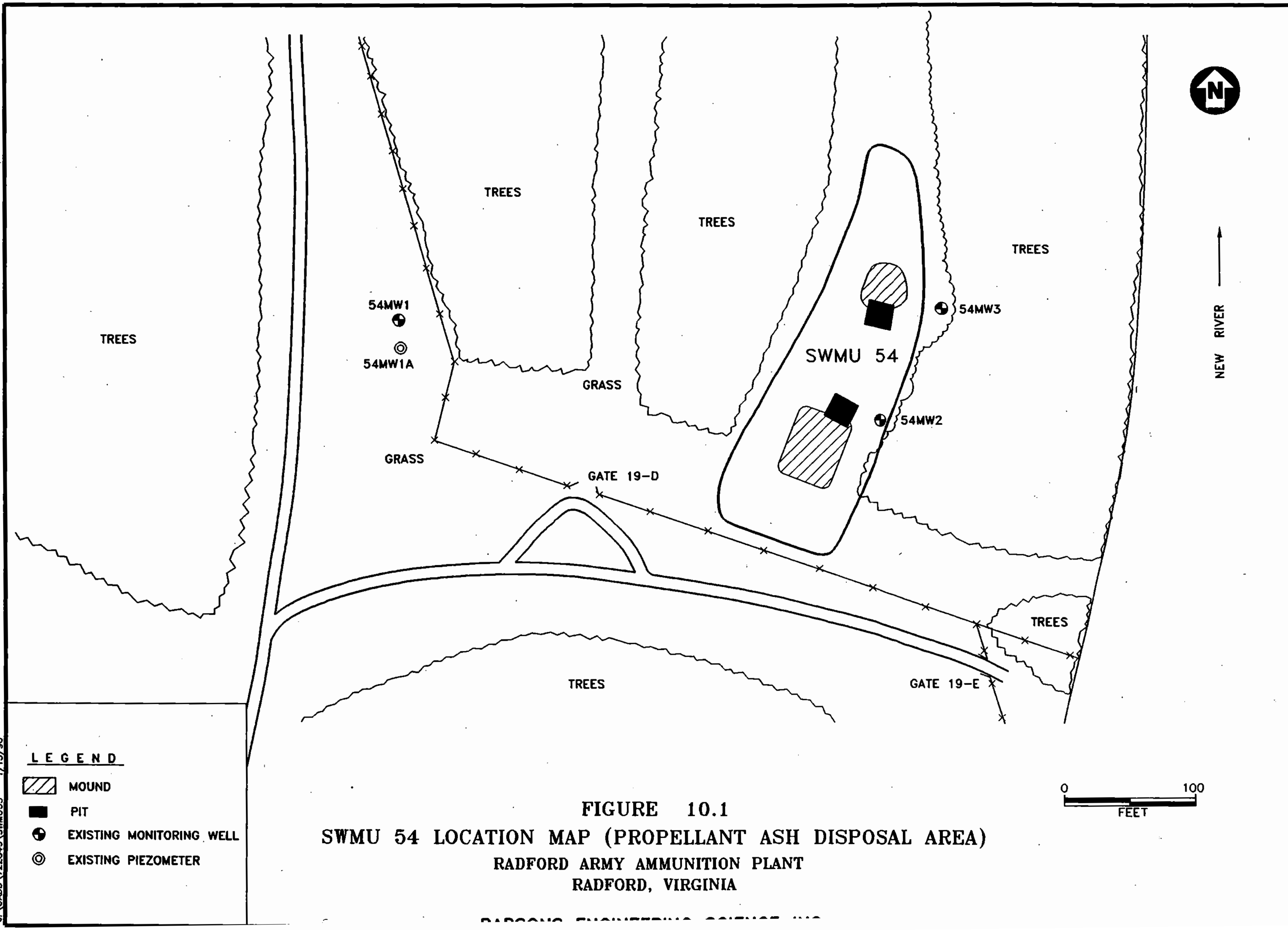


FIGURE 10.1

SWMU 54 LOCATION MAP (PROPELLANT ASH DISPOSAL AREA)

RADFORD ARMY AMMUNITION PLANT

RADFORD, VIRGINIA

PARSONS ENGINEERING SCIENCE, INC.

when it was discovered that problems encountered during construction of the well had compromised the quality of the groundwater.. 54MW1A is still used as a piezometer.

10.2.0.3. Results of the 1992 groundwater sampling at SWMU 54 are summarized in Table 10.1. Upgradient well data, HBNs (from the RCRA permit), and RBCs for tap water (USEPA, 1994) are also listed in the table for comparison. The results of the chemical analysis of the groundwater samples collected during the VI by Dames & Moore (1992b) indicated that low concentrations of two explosives and one VOC were present in groundwater samples collected downgradient from the disposal area. Eleven metals were detected in the three groundwater samples collected at SWMU 54. Four of the metals (aluminum, arsenic, silver, and zinc) were detected in the upgradient sample only, but were reported at levels slightly greater than the analytical detection limits. Concentrations of metals in both downgradient samples were similar to those in the upgradient sample (54MW1). Concentrations of all metals in downgradient wells were one or more orders of magnitude less than HBN or RBC criteria and were not identified as a concern. Two explosives, 2,4,6-TNT and HMX, were detected in downgradient groundwater samples 54MW2 and 54MW3, respectively, but were not detected in the upgradient sample. The concentration of 2,4,6-TNT was nearly one order of magnitude less than the HBN criterion but exceeded the RBC. HMX was detected at a concentration nearly three orders of magnitude less than the HBN criterion.

10.2.0.4. Geophysical methods were employed at SWMU 54 during the VI to delineate the boundaries of the area or locate buried materials. Electromagnetic (EM) and magnetic surveys were conducted to map possible locations of ash disposal. The survey covered an area 135 feet by 300 feet. Dames & Moore concluded that the anomalies in the EM and magnetic data centered at the southern mound and pit appear to be from a combination of buried conductive materials and metals, and the anomaly in the EM data found at the northern mound and pit appears to indicate burial of non-metallic material (Dames & Moore, 1992b). The pits in these two areas appear to be borrow areas for cover material for the mounds (Dames & Moore, 1992b).

TABLE 10.1
VI DATA 1992
SUMMARY OF ANALYTICAL DATA
FOR GROUNDWATER SAMPLES COLLECTED AT SWMU 54
RADFORD ARMY AMMUNITION PLANT, VIRGINIA

	PQLs	No. of Samples	Concentration Range 6 Feb 92 - 7 Feb 92 23.0 ft - 25.0 ft	Upgradient (54MW1) 6 Feb 92 45.0 ft	HBN	RBC Tap Water
TAL Inorganics (μg/L)						
Aluminum	141	2	LT 141	154	101,500	110,000
Arsenic	10	2	LT 2.54	5.4	50	0.038
Barium	20	2	104	97.2	1,000	2,600
Calcium	500	2	71,600 - 74,000	59,100	NSA	NA
Iron	38.1	2	63.6 - 74.5	81.7	NSA	NA
Magnesium	500	2	25,000 - 34,500	26,300	NSA	NA
Manganese	2.75	2	7.38 - 59.5	17	3,500	180
Potassium	375	2	1,990 - 2,320	1,630	NSA	NA
Silver	2	2	LT 0.25	0.255	50	180
Sodium	500	2	5,400 - 6,350	3,140	NSA	NA
Zinc	50	2	LT 21.1	23.1	7,000	11,000
Explosives (μg/L)						
246 TNT	0.635	2	LT 0.635 - [2.81]	LT 0.635	11.7	2.2
HMX	1.21	2	LT 1.21 - 3.07	LT 1.21	1,750	NA
Volatiles (μg/L)						
Carbon Disulfide	5	2	7.03 - 13.6	1.25	4,000	21
Semivolatiles (μg/L)						
	NA	2	ND	ND	NSA	NA
Semivolatile TICs (μg/L)						
Cyclopentanone	NA	2	ND - 5 S	10 S	NSA	NA
Mesityl Oxide	NA	2	ND	4 S	NSA	NA
Total Unknown TICs	NA	2	ND	(1)6	NSA	NA
Other						
Total Organic Carbon (μg/L)	1,000	2	3.67 - 5.45	10.5	NSA	NA
Total Organic Halogens (μg/L)	1	2	117 - 138	158	NSA	NA
pH	NA	2		6.99 - 7.02	7.29NSA	NA

HBN Health-based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumptions consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).10 S.
LT Concentration is reported as less than the certified reporting limit.
NA Not available:
ND Analyte was not detected.
NSA No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
PQL Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given anaytical method.
RBC Risk-based concentration provided by USEPA (USEPA 1994)
S Results are based on an internal standard; flag is used for TICs detected in library scans.
TAL Target analyte list.
TICs Tentatively identified compounds that were detected in the GC/MS library scans.
μg/L Micrograms per liter.
( ) Parentheses are used to indicate the number of unknown TICs that were detected in either the volatile or semivolatile GC/MS library scans. The number beside the parentheses is the total concentration of all TICs detected in each respective scan.
[] Brackets indicate that the detected concentration exceeds the HBN or RBC.
From Dames & Moore, 1992b

10.3 SUMMARY OF RFI FIELD ACTIVITIES

10.3.0.1. To define the extent of ash and the limits of soil contamination for the RFI, discrete soil samples were collected from around and below the north and south mounds. A total of 16 soil borings were installed. The sample locations shown in Figure 10.2 were based on the previous VI field sampling and geophysical investigations of SWMU 54. The soil boring proposed for the center of the north mound could not be obtained because of drill rig access problems; a hand augered soil sample was collected instead. Two soil samples (shallow and deep) were taken from each boring with the exception of the hand augered one (54SB15).

10.3.0.2. One composite sample of the ash was collected from each mound for waste characterization purposes. Groundwater samples were collected from each of the three monitoring wells. The analytical parameters for all the samples are indicated on Tables 4.3 and 4.4. A summary of the RFI field activities is presented in Table 10.2.

10.4 ENVIRONMENTAL SETTING

10.4.1 Topography and Site Layout

10.4.1.1. SWMU 54 is generally a level area with a ground surface elevation of approximately 1,700 feet above mean sea level. The SWMU is an elongated triangular grass covered area, approximately 300 feet long by 100 feet wide with two prominent piles of soil and ash beside two 3-5 foot deep pits. The soil/ash piles are referred to as the north and south mounds; the pits appear to be associated with borrow areas for each mound. The north mound is approximately 6-10 feet high and the south mound is approximately 4-6 feet high.

10.4.1.2. The SWMU is bordered to the east, west, and north by tree-covered areas and to the south by a grassy flat area which leads to a tree-covered area approximately 150 feet farther south. The triangular area is physically outside of the facility (outside the gate), with direct access from the New River. The river is approximately 150 feet east of the SWMU, flowing directly north before meandering westward. There are essentially no other buildings or active areas in the vicinity.

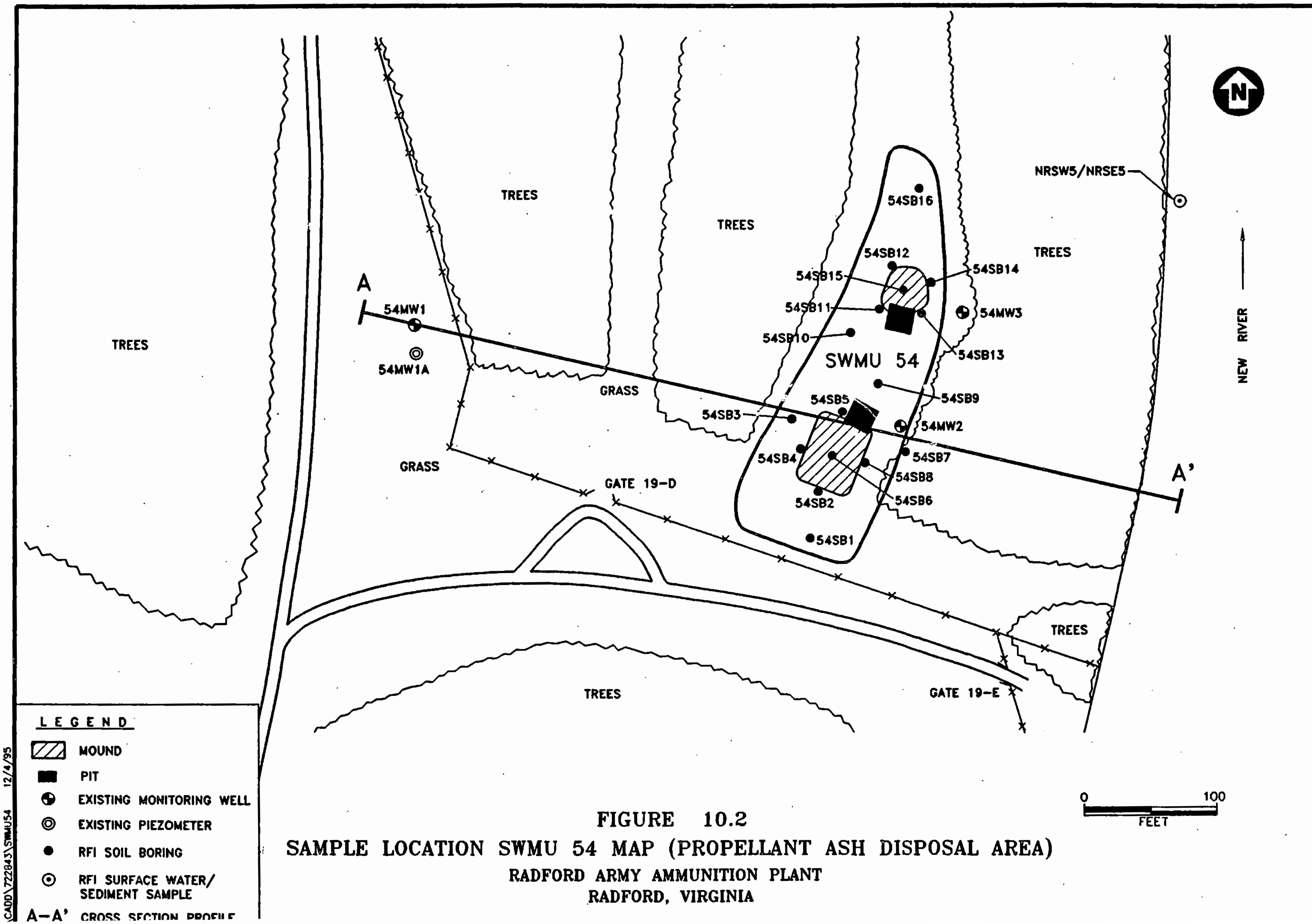


FIGURE 10.2
SAMPLE LOCATION SWMU 54 MAP (PROPELLANT ASH DISPOSAL AREA)
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

TABLE 10.2

SUMMARY OF SWMU 54 RFI FIELD ACTIVITIES
RADFORD ARMY AMMUNITION PLANT

SWMU	Monitoring Wells Sampled*	Soil Boring Samples	Depth (Feet Below Ground Surface)	Geotechnical Samples/Depth	Waste Ash Samples
54	54MW1	54SB1A2	0-2	54SB1 (15-17)	54SS1 (Composite)
	54MW2	54SB1B22	20-22	54SB2 (10-12)	54SS2 (Composite)
	54MW3	54SB2A2	0-2	54SB3 (10-12)	
		542B2B17	15-17	54SB4 (5-7)	
		54SB3A2	0-2	54SB5 (15-17)	
		54SB3B17	15-17	54SB6 (15-20)	
		54SB4A2	0-2	54SB7 (10-12)	
		54SB4B17	15-17	54SB8 (15-17)	
		54SB5A2	0-2	54SB9 (10-12)	
		54SB5B17	15-17	54SB10 (10-12)	
		54SB6A2	0-2	54SB11 (15-17)	
		54SB6B15	10-15	54SB12 (5-7)	
		54SB7A2	0-2	54SB13 (5-7)	
		54SB7B17	15-17	54SB14 (7-9)	
		54SB8A2	0-2	54SB16 (10-12)	
		54SB8B17	15-17		
		54SB9A7	5-7		
		54SB9B17	15-17		
		54SB10A2	0-2		
		54SB10B17	15-17		
		54SB11A2	0-2		
		54SB11B17	15-17		
		54SB12A2	0-2		
		54SB12B17	15-17		
		54SB13A2	0-2		
		54SB13B22	20-22		
		54SB14A2	0-2		
		54SB14B15	11-12		
		54SB15A6	4-6		
		54SB16A2	0-2		
		54SB16B12	10-12		
		54SB10B20 (Dup. of 54SB10B17)			
		54SB16B25 (Dup. of 54SB16B12)			

*Field measurements of pH, temperature and conductivity were also collected.

10.4.2 Geology

10.4.2.1. The geology of SWMU 54 was characterized by drilling 16 soil borings for the RFI and utilizing existing information obtained from the installation of three monitoring wells for the VI (Dames & Moore, 1992a). The vertical extent of all drilling activities was approximately 60 feet, ranging from 1708 feet above mean sea level (amsl) to 1648 feet amsl.

10.4.2.2. Geological samples were categorized under the Unified Soil Classification System (USCS) in accordance with the work plan. One geotechnical sample per boring was collected from 15 of the 16 borings at different discrete depths (see Table 4.5) and submitted for laboratory analysis to determine USCS designation. All other samples, including those obtained for chemical analysis or general characterization by split spoon or Moss spoon, were given a USCS designation by the project geologist. This information, supplemented by the lithologic logs from the monitoring wells, was used to prepare the geologic cross section presented as Figure 10.3. A west to east (A-A') cross section profile line is shown on Figure 10.2.

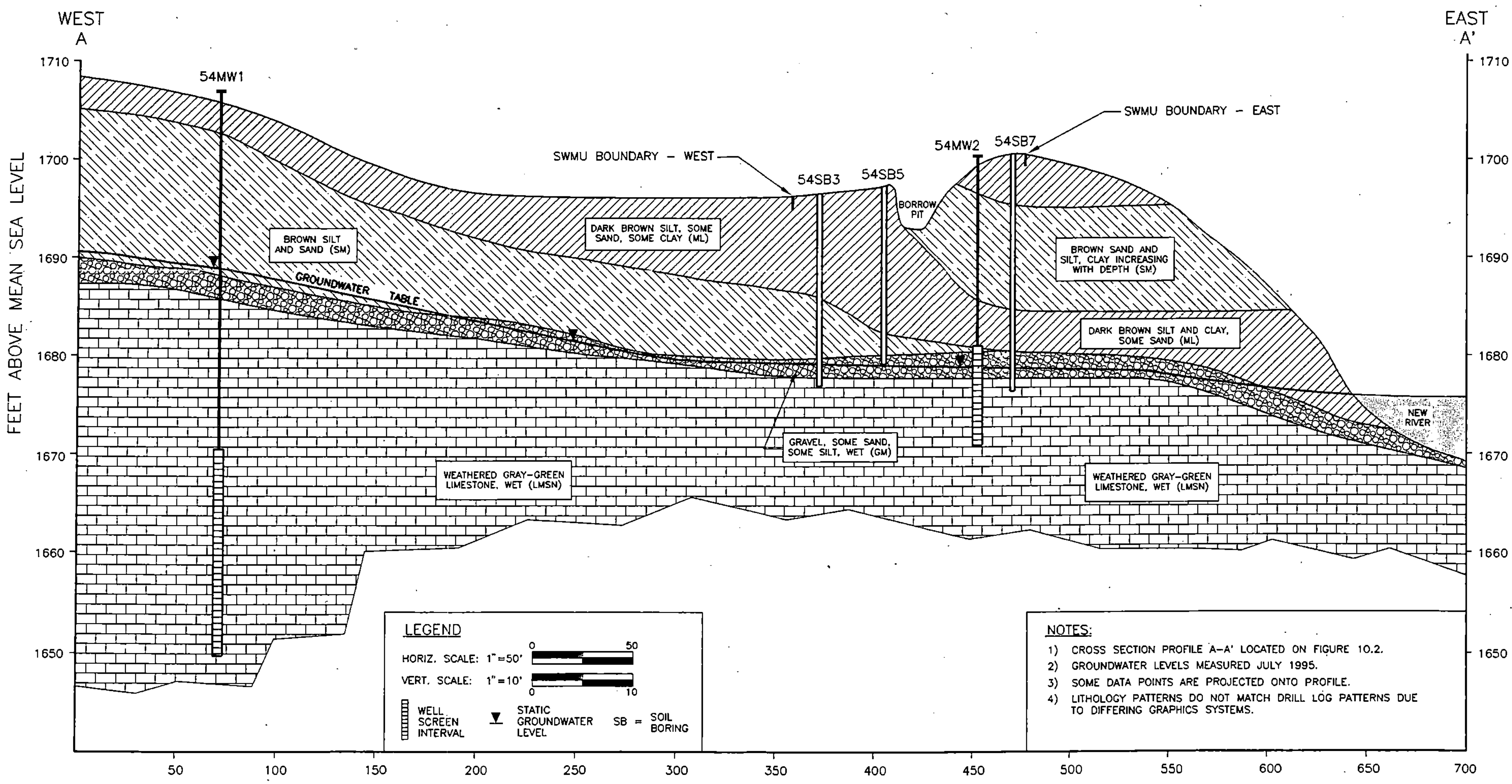
10.4.2.3. The geology of SWMU 54 generally consisted of unconsolidated alluvial sediments (river terrace deposits) overlying a weathered limestone of the Elbrook Formation. The geology was very consistent across the study area. The cross section displays sediments gently dipping toward the New River. Generally, a dark brown silt with some sand and clay (ML), 5 to 15 feet thick, overlaid a brown silt and sand (SM). Below the SM layer, a thin gravel sequence (GM) with some silt and little sand was encountered. The GM layer was typically wet. The bedrock beneath the GM layer was limestone, but in some cases a weathered gray siltstone was found. Directly below the SWMU, the limestone bedrock was encountered at approximately 20-23 feet below ground surface (bgs). The limestone was a distinctive gray-green in color. It was penetrated by the monitoring well borings, but not the 16 soil borings which encountered auger refusal at the bedrock interface. The rock samples at the bedrock interface were determined by hydrochloric acid effervescence to be limestone.

10.4.3 Hydrogeology

10.4.3.1. The three monitoring wells present at SWMU 54 (Figure 10.1) were installed during the VI conducted by Dames & Moore. In July 1995, groundwater was

FIGURE 10.3
SWMU 54 GEOLOGIC CROSS SECTION (A–A')

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



PARSONS ENGINEERING SCIENCE INC

Figure 10.3

measured at 18.7 feet bgs at the upgradient well (54MW1) and at about 23 feet bgs at the two downgradient wells (54MW2 and 54MW3). In the soil boring locations, the groundwater table was encountered within a gravel layer. The gravel layer was consistently observed directly above the weathered limestone bedrock, between 17 and 22 feet bgs.

10.4.3.2. Groundwater occurrence and movement at SWMU 54 does not appear to be complex. Groundwater at this SWMU is present within a relatively shallow unconfined aquifer consisting of unconsolidated alluvial sediments and the underlying weathered siltstone and limestone of the Elbrook Formation. The potentiometric surface of the groundwater for SWMU 54 is shown in cross-section in Figure 10.3 and in plan view in Figure 10.4. Groundwater consistently occurs in the gravel layer overlying the bedrock. Groundwater flows to the east, toward the New River, at a hydraulic gradient of approximately 0.026 ft/ft. Groundwater appears to discharge directly into the New River.

10.4.3.3. Well construction details for the SWMU 54 monitoring wells are shown in Table 4.1. Field data collected during the July 1995 sampling event is summarized in Table 10.3. Field data included photoionization detector (PID) readings of the well headspace in parts per million (ppm), pH, temperature, and conductivity of the groundwater. The groundwater elevations used to construct the potentiometric surface map (Figure 10.3) are also shown.

10.4.4 Surface Water

10.4.4.1. The New River is approximately 150 feet east of SWMU 54. In this vicinity, the New River flows parallel to SWMU 54 to the north before, meandering westward. Based on topography, surface water runoff is expected to flow eastward toward the river. According to RAAP utility maps, there are no manholes, catch basins, or storm drains located in the vicinity of SWMU 54.

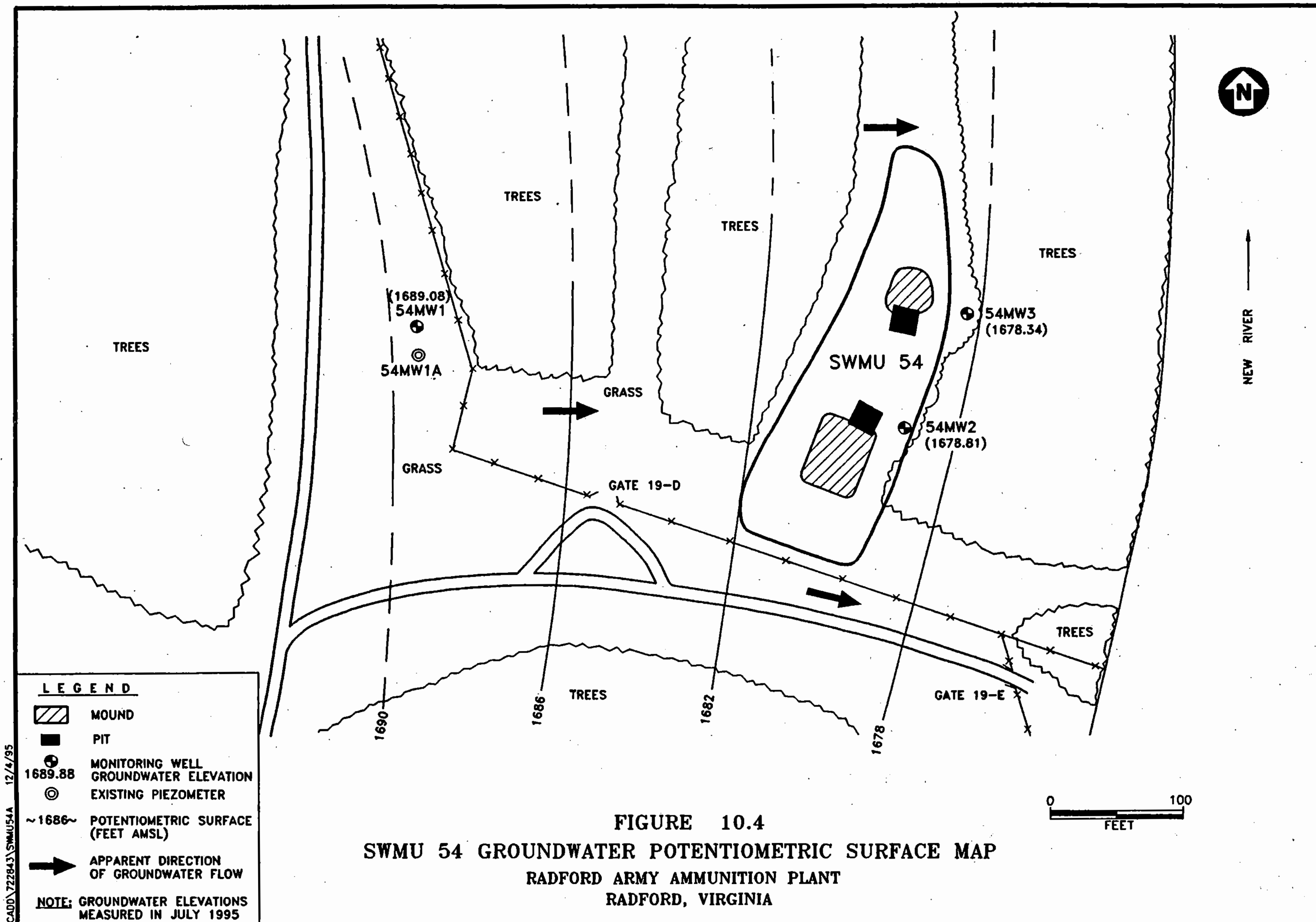


FIGURE 10.4
SWMU 54 GROUNDWATER POTENTIOMETRIC SURFACE MAP
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

TABLE 10.3
SWMU 54: GROUNDWATER FIELD DATA
RADFORD ARMY AMMUNITION PLANT

Well Name	Date	Depth to Bottom (ft)	Depth to Water (ft)	Groundwater Elevation*(ft)	PID (ppm)	pH	Temperature (degrees F)	Conductivity us/cm
54MW1	7-15-95	52.0	18.70	1689.08	0.0	7.77	76.0	490
54MW2	7-17-95	28.0	22.60	1678.81	0.0	NA	NA	NA
54MW3	7-17-95	30.0	23.81	1678.34	0.0	6.98	81.0	406

* Feet above mean sea level
NA: No data due to instrument malfunction.

10.5 NATURE AND EXTENT OF CONTAMINATION

10.5.0.1. A summary of all positive results (detected compounds) for soil and aqueous samples collected at SWMU 54 is presented in Tables 10.4 and 10.5, respectively. The chemicals of concern (COCs) for SWMU 54 were determined in accordance with the methods described in Section 6. The focus of the section is on the COCs identified as potential human health threats as detailed in the subsequent Risk Assessment subsections.

10.5.1 Nature of Contamination

10.5.1.1 Subsurface soils

10.5.1.1.1. Six COCs were identified in the subsurface soils at SWMU 54, including mercury, lead, and the explosives, 2,4-Dinitrotoluene, 2,4,6-Trinitrotoluene, HMX, and RDX. Mercury and 2,4,6-Trinitrotoluene were found at concentrations considered to be a potential human health risk. Both compounds were considered to be the risk drivers for soils at SWMU 54.

10.5.1.1.2. 2,4,6-TNT was detected in eight soil boring samples, ranging in concentration from 2.85 ug/g in 54SB7A2 to 6527.78 ug/g in 54SB6B15. Mercury was found in six soil boring samples, ranging in concentration from 0.09 ug/g in 54SB1A2 to 72.13 ug/g in 54SB6A2. The background concentration for mercury in soils at shallow depths (B horizon) is 1.5 ug/g. The C horizon background for mercury is 2 ug/g.

10.5.1.1.3. Lead was not found at levels considered to pose a human health threat, although it did exceed background. The B horizon background concentration is 161.81 ug/g; the C horizon background level is 140.67 ug/g. Lead was detected in all samples from all soil borings at SWMU 54. Concentrations ranged from 5.77 ug/g in 54SB1B22 to 3789.73 ug/g in 54SB6A2. The TCLP lead concentration exceeded regulatory levels in a composite waste ash sample collected from the southern mound. Positive results for 2,4-Dinitrotoluene were found in three samples at this SWMU. The maximum concentration (56.67 ug/g) was detected in sample 54SB615. This explosive was also detected in the shallow sample taken from boring 54SB6 at a concentration of 25.31 ug/g. The third positive result was in sample 54SB3A2.

TABLE 10.4
POSITIVE RESULTS TABLE OF SWMU 54 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54SB1A2	54SB1B22	54SB2A2	54SB2B17	54SB3A2	54SB3B17	54SB4A2
METALS (ug/g)							
Arsenic			3.27 J4				
Lead	716.80 J6	5.77 J6	2354.26 J6	14.23 J6	321.84 J6	14.74 J6	84.26 J6
Silver	0.07 J4		0.03 J4	0.03 J4	0.03 J4	0.04 J4	0.04 J4
Barium	164.51 J1	307.44 J1	224.22 J1	175.46 J1	178.16 J1	87.63 J1	313.51 J1
Beryllium	0.93 J4		1.76 J4	1.33 J4	1.11 J4		1.78 J4
Cadmium	2.40 J4						
Chromium	25.38 J6	9.80 J6	27.91 J6	29.45 J6	28.16 J6	37.76 J6	35.56 J6
Nickel	11.66 J4	6.23 J4	10.25 J4	16.69 J4	13.45 J4	10.26 J4	21.44 J4
Mercury	0.09 J4		0.13 J4		5.06 J4	0.21 J4	
EXPLOSIVES (ug/g)							
2,4,6-Trinitrotoluene			4.41 J4		2988.51 J4	48.42 J4	
2,4-Dinitrotoluene					12.76 J4		
2,6-Dinitrotoluene							
Cyclotetramethylenetetranitramine (HMX)					4.68		
Cyclonite (RDX)					1.98 J4		
OTHER (ug/g)							
Total Organic Carbon		95514.20					

TABLE 10.4
POSITIVE RESULTS TABLE OF SWMU 54 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54SB4B17	54SB5A2	54SB5B17	54SB6A2	54SB6B15	54SB7A2	54SB7B17
METALS (ug/g)							
Arsenic				4.08 J4			
Lead	8.36 J6	39.90 J6	16.82 J6	3789.73 J6	430.56 J6	50.29 J6	22.79 J6
Silver	0.03 J4	0.04 J4	0.05 J4	0.30 J4			
Barium	108.30 J1	281.80 J1	244.59 J1	1077.02 J1	362.50 J1	138.29 J1	420.91 J1
Beryllium		1.55 J4	1.61 J4	1.11 J4	2.43 J4	0.82 J4	2.47 J4
Cadmium				11.75 J4			
Chromium	21.30 J6	34.54 J6	40.64 J6	136.92 J6	70.14 J6	24.00 J6	57.10 J6
Nickel	9.19 J4	21.20 J4	24.46 J4	16.99 J4	30.14 J4	12.34 J4	34.72 J4
Mercury				72.13 J4			
EXPLOSIVES (ug/g)							
2,4,6-Trinitrotoluene				4.71 J4	6527.78 J4	2.85 J6	
2,4-Dinitrotoluene				25.31 J4	56.67 J4		
2,6-Dinitrotoluene					112.50		
Cyclotetramethylenetetranitramine (HMX)					7.28 J9		
Cyclonite (RDX)							
OTHER (ug/g)							
Total Organic Carbon							

TABLE 10.4
POSITIVE RESULTS TABLE OF SWMU 54 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54SB8A2	54SB8B17	54SB9A7	54SB9B17	54SB10A2	54SB10B17	54SB10B20*
METALS (ug/g)							
Arsenic					4.28 J4		
Lead	229.75 J6	21.20 J6	20.85 J6	15.83 J6	205.56 J6	11.69 J6	13.16 J6
Silver				0.04 J4	0.07 J4	0.03 J4	0.03 J4
Barium	188.63 J1	243.14 J1	193.90 J1	201.01 J1	319.23 J1	158.09 J1	141.88 J1
Beryllium	1.15 J4	1.72 J4	1.39 J4	1.53 J4	1.81 J4	1.20 J4	1.03 J4
Cadmium							
Chromium	27.69 J6	40.15 J6	27.93 J6	37.56 J6	33.86 J6	29.78 J6	27.23 J6
Nickel	15.60 J4	25.56 J4	17.68 J4	22.61 J4	19.71 J4	18.01 J4	15.45 J4
Mercury						0.12 J4	
EXPLOSIVES (ug/g)							
2,4,6-Trinitrotoluene			48.54 J4				11.67 J4
2,4-Dinitrotoluene							
2,6-Dinitrotoluene							
[redacted]							
OTHER (ug/g)							
Total Organic Carbon						3088.24	1830.66

* 54SB10B20 is a duplicate sample of 54SB10B17

TABLE 10.4
POSITIVE RESULTS TABLE OF SWMU 54 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54SB11A2	54SB11B17	54SB12A2	54SB12B17	54SB13A2	54SB13B22	54SB14A2
METALS (ug/g)							
Arsenic							
Lead	91.13 J6	12.11 J6	21.22 J6	13.28 J6	134.97 J6	8.23 J6	36.56 J6
Silver					0.07 J4		
Barium	223.57 J1	175.55 J1	235.96 J1	248.34 J1	226.99 J1	118.64 J1	153.30 J1
Beryllium	1.49 J4	1.34 J4	1.54 J4	1.82 J4	1.42 J4		0.89 J4
Cadmium							
Chromium	33.17 J6	32.93 J6	36.08 J6	46.48 J6	31.29 J6	32.32 J6	20.52 J6
Nickel	20.05 J4	18.89 J4	20.10 J4	26.43 J4	18.90 J4	13.20 J4	12.38 J4
Mercury							
EXPLOSIVES (ug/g)							
2,4,6-Trinitrotoluene							
2,4-Dinitrotoluene							
2,6-Dinitrotoluene							
Cyclotetramethylenetetranitramine (HMX)							
Cyclonite (RDX)							
OTHER (ug/g)							
Total Organic Carbon							

TABLE 10.4
POSITIVE RESULTS TABLE OF SWMU 54 - Solid Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54SB14B15	54SB15A6	54SB16A2	54SB16B12	54SB16B25*
METALS (ug/g)					
Arsenic					
Lead	13.25 J6	28.40 J6	31.82 J6	14.81 J6	13.68 J6
Silver					
Barium	166.27 J1	338.27 J1	231.33 J1	203.70 J1	237.56 J1
Beryllium	1.08 J4	1.93 J4	1.47 J4	1.48 J4	1.77 J4
Cadmium					
Chromium	34.10 J6	45.93 J6	34.27 J6	34.20 J6	43.53 J6
Nickel	20.12 J4	26.05 J4	20.56 J4	20.12 J4	24.25 J4
Mercury					
EXPLOSIVES (ug/g)					
2,4,6-Trinitrotoluene					
2,4-Dinitrotoluene					
2,6-Dinitrotoluene					
Cyclotetramethylenetetranitramine (HMX)					
Cyclonite (RDX)					
OTHER (ug/g)					
Total Organic Carbon	1903.61			2740.74	2860.70

* 54SB16B25 is a duplicate sample of 54SB16B12

TABLE 10.5
POSITIVE RESULTS TABLE OF SWMU 54 - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	54MW1	54MW1 Dissolved	54MW2	54MW2 Dissolved	54MW3	54MW3 Dissolved
METALS (ug/l)						
Arsenic	20.7	15.1				
Lead	16.6	6.33	9.31			
Barium	1060	519	144	89.5	175	106
Beryllium	20	13.2	3.19	2.96	4.09	2.82
Chromium	66.7	26.6				
Nickel	37.4					
Antimony	110	97.5				
EXPLOSIVES (ug/l)						
Cyclotetramethylenetetranitramine (HMX)			4.63		3.18 J10	
OTHER (ug/l)						
Total Organic Carbon	1170					
Total Organic Halogens	10.8		13 J7			

10.5.1.1.4. HMX was detected in two soil boring samples, 54SB3A2 and 54SB6B15. The maximum concentration was 7.28 ug/g in 54SB6B15. RDX was only found in 54SB3A2 at 1.98 ug/g. Other compounds with positive results, which did not exceed background levels or levels considered to be a human health threat, included arsenic, silver, barium, beryllium, cadmium, chromium, nickel, and 2,6-Dinitrotoluene.

10.5.1.2 Groundwater

10.5.1.2.1. Seven COCs (six metals and one explosive) were identified in the groundwater in SWMU 54. They included antimony, arsenic, barium, beryllium, chromium (as chromium III), lead, and the explosive, HMX. Antimony, arsenic, and beryllium were found at concentrations considered to be a potential human health risk. All of these compounds were categorized as the risk drivers for the groundwater at SWMU 54.

10.5.1.2.2. Arsenic and antimony were only detected in the sample from 54MW1, at a concentration of 15.1 ug/l (dissolved) and 97.5 ug/l (dissolved), respectively. Beryllium was found in the samples from all three monitoring wells, ranging from 2.82 ug/l to 13.2 ug/l beryllium (dissolved). The maximum concentration was detected in the sample from 54MW1. Barium was also found in the samples from all three wells. The maximum detection was from the 54MW1 dissolved sample, 519 ug/l. The explosive, HMX, was found in the samples from 54MW2 (4.63 ug/l) and 54MW3 (3.18 ug/l).

10.5.1.2.3. Of the remaining COCs, dissolved lead was only detected in the sample from 54MW1 (6.33 ug/l). Total lead was detected in 54MW1 and 54MW2 at 16.6 ug/l and 9.31 ug/l, respectively. Chromium was only detected in the sample from 54MW1. A positive result for nickel was not at levels considered to be a COC. It was detected in the total nickel sample from 54MW1.

10.5.2 Extent of Contamination

10.5.2.1 Subsurface Soils

10.5.2.1.1. The maximum concentration of 2,4,6-TNT was found in the 12-13 feet bgs sample (taken from that interval in a five foot Moss spoon) of boring 54SB6. This boring was located in the center of the southern ash disposal mound. Approximately 40 feet west of that boring, the next highest concentration was found, 2988.51 ug/g in 54SB3A2. However, this sample was collected from 1-2 feet bgs. The next highest results were found in the deep sample from 54SB3 and in 54SB9A7 (mid-way between the two mounds at 5-7 feet bgs). The other explosives identified as COCs, RDX and HMX, were only found together in 54SB3A2; HMX was also found in the deep sample from boring 54SB6. That boring sample was also positive for 2,6-Dinitrotoluene.

10.5.2.1.2. The highest mercury detection was found in 54SB6A2, in the southern mound; this sample also contained the maximum lead concentration. The next highest mercury concentration, 5.06 ug/g was detected in the 54SB3A2 sample. Mercury was generally found at significant levels in the shallow B horizon samples. None of the deep boring samples exceeded the mercury background level.

10.5.2.1.3. In general, the metals and explosives contamination was found in the shallow samples, approximately 1-3 feet bgs. The most significant results were in the samples from two borings, 54SB3 and 54SB6. Of these two, only 54SB6 contained notable contaminant concentrations in the deep sample (12-13 feet bgs). These borings are either in or near the southern disposal mound; the sample from the center of the northern mound, 54SB15 contained only one COC, but at levels below background.

10.5.2.2 Groundwater

10.5.2.2.1. Of the risk driver compounds, all of the maximum metals concentrations were found in the samples from 54MW1. This well has been shown to be upgradient from the ash disposal areas of SWMU 54. [redacted] The explosive COC compound, [redacted], was found in the samples from [redacted] The highest concentration was found in the sample from the well (54MW2) nearest the southern mound where most of the soil contamination was identified.

10.6 CONTAMINANT FATE AND TRANSPORT

10.6.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. At SWMU 54, both the surface water and groundwater are potential migration pathways to the New River. The areas of shallow soil contamination and ash layers are susceptible to periodic flooding of the New River and transport downstream. [redacted]

10.6.0.2. Soil and sediment are important media for chemical transport of the explosives compounds since they have a high affinity for organic matter and a low water solubility. When present in soil or sediments, explosives tend to remain bound to the soil particles and dissolve slowly into groundwater. Because of the high affinity for organic matter, the fate of these explosive compounds is often controlled by transport of particulates. 2,4,6-TNT, the explosive risk driver compound for subsurface soils at SWMU 54 was also found in the sediment sample (NRSE5) collected from the New River, just downstream of the SWMU; the concentration of 2,4,6-TNT in that sample was the highest detected in the New River sediments. Explosives, however, are not readily bioaccumulated by living organisms.

10.6.0.3. Mercury is generally immobile in the types of relatively clayey soils at the SWMU; it was not found in the New River sediments downstream of SWMU 54. Dissolved metals in the groundwater are mobile, but the risk driver compounds in SWMU 54 groundwater were not found in the surface water samples downstream of the SWMU. Only barium, which was identified as a COC for dissolved concentrations at SWMU 54, was found in downstream surface water samples. Arsenic and [redacted] which were risk drivers for dissolved groundwater at SWMU 54 were detected in the sediment sample NRSE5.

10.6.0.4. Subsurface transport of lead is generally minimal because of its low solubility and tendency to sorb to aquifer materials. However, lead was determined to be a COC in groundwater and subsurface soils at SWMU 54; although lead was not detected in the New River surface water sample, it was found in the associated sediment sample. Lead also exceeded the TCLP regulatory limit in the waste ash sample.

10.7 RISK ASSESSMENT

10.7.0.1. The propellant ash disposal area is unlined and contains areas where ash residue is visible on surface soils. Ash disposal reportedly occurred on the soil surface at this area. This does not limit the potential for emissions to the atmosphere and contaminants migrating from disposed ash to surface and subsurface soils, surface waters and groundwater.

10.7.0.2. At present, future land use at this SWMU is uncertain; SWMU 54 is located outside the RAAP fence and within 200 feet of the New River. Currently, ash is no longer disposed at this area. Potential future scenarios may consist of removing the ash and any associated contaminated soils, or installing a cap and closing this disposal area.

10.7.1 Summary of Chemicals of Potential Concern

10.7.1.0.1. The chemicals considered in the risk evaluation for groundwater at SWMU 54 include 6 metals (antimony, arsenic, barium, beryllium, chromium III and lead) and one explosive (HMX). The chemicals of concern for subsurface soils include 2 metals (lead and mercury), one volatile (2,4-dinitritoluene) and three explosives (2,4,6-trinitrotoluene, HMX and RDX).

10.7.1.1 Comparison to ARARs and TBCs for Groundwater and Soils

10.7.1.1.1. Groundwater in the vicinity of RAAP is not used for drinking water serving more than 25 people and therefore MCLs and MCLGs are not considered as ARARs for SWMU 31. In addition, there are no Federal or Commonwealth of Virginia standards relating chemical concentrations in soils to toxic effects on vegetation or wildlife. TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995).

10.7.2 Exposure Assessment

10.7.2.1 Potential Pathways and Receptors

10.7.2.1.1. Current exposure pathways at SWMU 54 are considered to have a low probability of completion, with the exception of the construction worker exposure scenario. At present, this area is no longer used for propellant ash disposal. Although current site workers have access to potentially contaminated surface soils with and areas of uncovered ash, surface soil samples from this SWMU did not exhibit positive detects for analytes other than reactive sulfite. SWMU 54 is located outside the RAAP boundary and within 200 feet of the New River; thus public access is not limited to exclude recreational users of the New River. However, the area between this SWMU and the river is densely vegetated which would prohibit contaminant exposure by recreational river users. This exposure pathway was determined to have a low probability of completion and was not quantified. In addition, the current groundwater pathway is not complete as this water is not used for drinking purposes.

10.7.2.1.2. Potential future routes of human exposure which were considered for SWMU 54 include site worker ingestion and dermal exposure to potentially contaminated groundwater.

10.7.2.1.3. The conceptual site model summary for SWMU 54 is presented in Figure 10.5 and includes exposure routes, potential receptors and the medium containing the potential contaminants of concern. All chemicals not eliminated by data validation were considered in the risk assessment for this SWMU.

10.7.2.2 Exposure Point Concentrations and Chronic Daily Intakes

10.7.2.2.1. Exposure point concentrations for the seven metals and one explosive detected in SWMU 54 (see Subsection 10.7.1) groundwater are listed in the tables in Appendix I. These concentrations range from 0.00158 mg/L (HMX) to 0.17 mg/L (barium). Exposure point concentrations for the contaminants of concern in subsurface soils (also see Section 10.7.1) range from 0.943 ppm (RDX) to 2,210 ppm (lead).

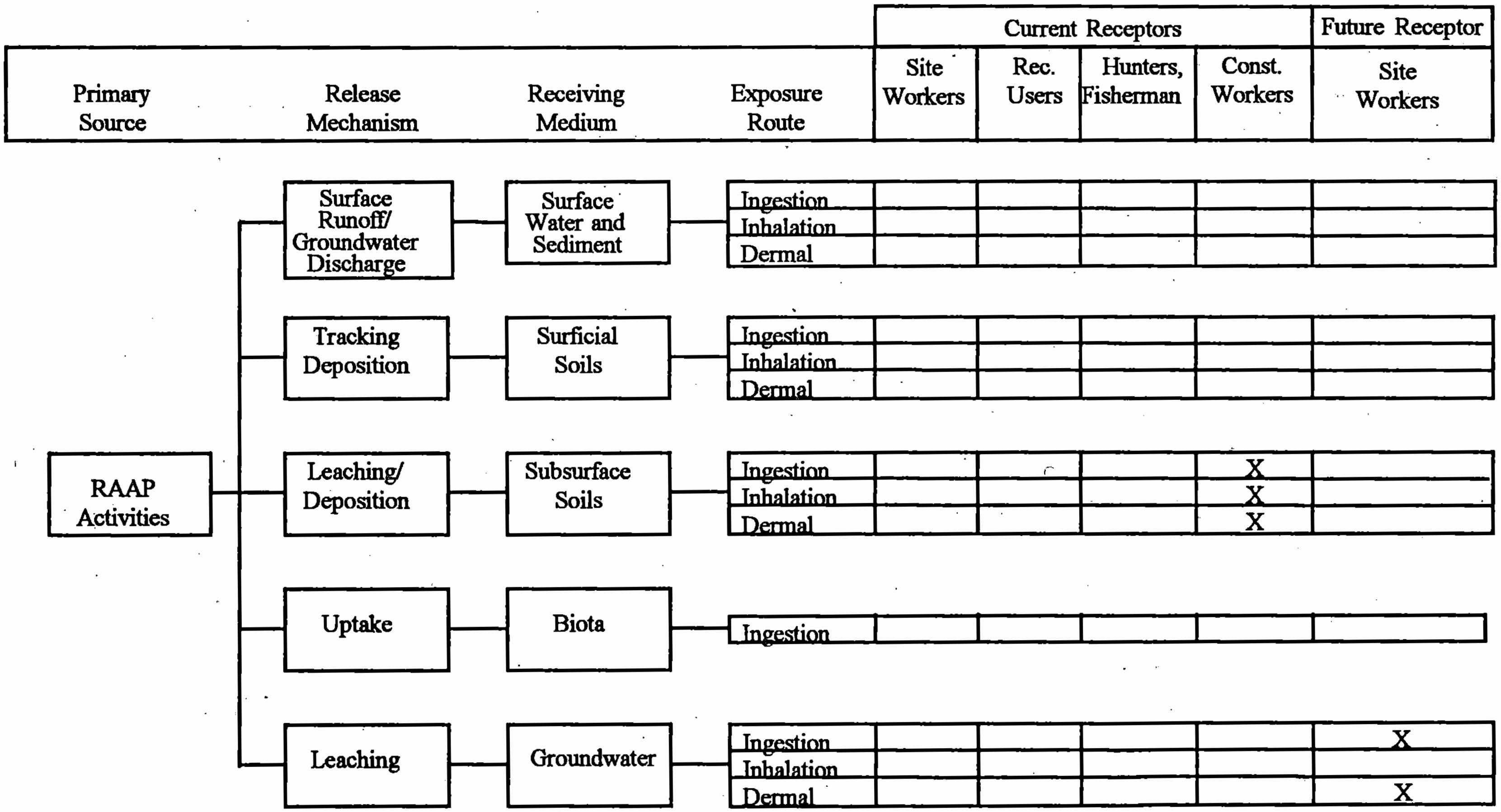
10.7.3 Risk Characterization

10.7.3.0.1. The carcinogenic risk and hazard index were calculated for the groundwater ingestion and dermal contact pathways (future site worker receptor) and subsurface soil ingestion, dermal contact, and inhalation of volatiles and particulates (construction worker). These calculations are presented in Appendix I. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

10.7.3.1 Non-carcinogenic Effects

10.7.3.1.1. The calculated hazard indices for the hypothetical future site worker groundwater ingestion scenario exceed acceptable levels primarily due to antimony and arsenic for CT and RME receptors. The primary risk driver for the ingestion scenario is

Figure 10.5
Conceptual Site Model for Current and Future Exposure Pathways
SWMU 54
Radford Army Ammunition Plant
Radford, Virginia



X = Pathways of potential concern
H = Hunter scenario

antimony, with calculated hazard indices for CT and RME receptors being 0.27 and 1.09, respectively.

10.7.3.1.2. The calculated hazard index for the construction worker subsurface soil ingestion scenario exceeds acceptable levels primarily due to 2,4,6-trinitrotoluene (2,4,6-TNT) for RME receptors (HI = 3.64). Mercury is the only other compound which shows a hazard index, and this is below one for both CT and RME receptors. The primary risk drivers for the construction worker dermal contact exposure scenario are mercury and 2,4,6-TNT. The calculated hazard indices for CT and RME receptors for mercury are 1.77 and 2.29, respectively. The calculated hazard indices for CT and RME receptors for 2,4,6-TNT are 1.20 and 1.55, respectively. The construction worker inhalation of volatiles and particulates exposure scenarios did not result in hazard indices exceeding one.

10.7.3.2 Carcinogenic Effects

10.7.3.2.1. The calculated cancer risks for the hypothetical future site worker groundwater dermal contact scenario are within the USEPA target risk range primarily due to beryllium, for CT and RME receptors. Beryllium was calculated to have the highest cancer risk, with calculations for CT and RME receptors being 1.64×10^{-6} and 3.28×10^{-5}, respectively. Total cancer risks for the hypothetical future site worker groundwater ingestion scenario are also within the USEPA target risk range due to arsenic and beryllium. Again, the primary risk driver for this exposure scenario was beryllium, with risks for CT and RME receptors being 3.60×10^{-6} and 7.20×10^{-5}, respectively.

10.7.3.2.2. The calculated cancer risks for the construction worker subsurface soil ingestion exposure scenario are within the USEPA target risk range for RME receptors, due to 2,4,6-TNT (1.57×10^{-6}). Calculated cancer risks for the dermal contact exposure scenario were below the USEPA target risk range. There were no calculated cancer risks for the future construction worker inhalation of volatiles and particulates exposure scenarios.

10.7.4 Uncertainty Analysis

10.7.4.0.1. Data collection/evaluation uncertainty may be relevant at SWMU 54 due to the types and numbers of samples collected. Analyses performed on the surface soil samples from the propellant ash disposal area only yielded positive results for reactive sulfite and these results are not quantifiable for risk assessment purposes. It has also been reported that the propellant ash is uncovered in several places at this SWMU and current site workers may be exposed to residual ash. Current site worker risks from potential contamination through exposure to surface soils are not quantifiable and unknown, and this may underestimate the risk from this site.

10.7.4.0.2. Many metals detected at this site in groundwater and subsurface soils are naturally occurring and in some cases (i.e., subsurface soil), statistical methods were used to distinguish site-related from non-site-related metals. In this case, all metals detected in groundwater were retained as if they were site-related. The calculations have shown to present unacceptable risks due to these metals and this could be an overestimate due to natural metals concentration in groundwater.

10.7.4.0.3. SWMU 54 is located outside the RAAP boundaries and is within 150 feet of the New River, which is used by recreational users and fishermen. Although there is dense vegetation serving as a natural barrier which may prevent recreational users from coming into contact with potentially contaminated surface soils, there is the possibility of the completion of this exposure pathway. This pathway was determined to be low probability and was not quantified. This may tend to underestimate risk from this SWMU.

10.7.4.0.4. Another area of uncertainty in evaluating human health risk from SWMU 54 is toxicity assessment. Oral and dermal slope factors are not available for some of the metals and explosives which were detected in groundwater and subsurface soils. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

10.7.4.0.5. The inhalation of volatiles and particulates from soils may also be another source of uncertainty for this SWMU. This exposure scenario was evaluated for construction workers in this area. The chemicals of concern in subsurface soils do not have associated inhalation RfDs or slope factors, and therefore the risks from this pathway are not quantifiable. This may tend to underestimate the risk.

10.8 RISK SUMMARY

10.8.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for site worker receptors potentially exposed to multiple chemicals in groundwater during domestic use, and construction workers potentially exposed to multiple chemicals in subsurface soils. The groundwater and subsurface soil pathway calculations were summarized and are presented in Table 10.6. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 1 x 10^{-4} to 1 x 10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 1 x 10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index less than one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

10.8.0.2. At SWMU 54, the site worker RME receptors' total hazard index is greater than one for ingestion of groundwater. Also, the total cancer risk value for these scenarios is within the USEPA target risk range of 1 x 10^{-6} to 1 x 10^{-4}. These values indicate a potential for noncarcinogenic and carcinogenic adverse human health effects for this receptor.

10.8.0.3. The construction worker CT and RME receptors' total hazard index is greater than one. The RME receptors' total cancer risk is within the USEPA target risk range. These values indicate a potential for noncarcinogenic and carcinogenic adverse human health effects for the exposure scenarios for the RME.

10.9 SWMU 54 SUMMARY

10.9.0.1. The groundwater associated with SWMU 54 appears to reside in the alluvial sediments overlying the limestone bedrock; groundwater flow direction is toward the New River. Groundwater, subsurface soils, and waste ash samples were collected to characterize SWMU 54. Additionally, a surface water and sediment sample was collected from the New River at the likely discharge point of groundwater from beneath the SWMU.

Table 10.6
Summary of Human Health Risk
SWMU 54
Radford Army Ammunition Plant

Receptor	Pathways	HI CT	HI RME	Cancer Risk CT	Cancer Risk RME
Site Worker	Ingestion of Groundwater	0.30	1.21	4.32E-06	8.65E-05
	Dermal Contact with Groundwater	0.13	0.50	1.64E-06	3.29E-05
Total for Site Workers		0.43	1.71	5.96E-06	1.19E-04
Construction Worker	Ingestion of Subsurface Soil	0.82	3.92	8.20E-08	1.57E-06
	Dermal Contact with Subsurface Soil	2.97	3.85	1.29E-07	6.72E-07
	Inhalation of Subsurface Soil Volatile	0	0	0.00E+00	0.00E+00
	Inhalation of Subsurface Soil Particul	0	0	0.00E+00	0.00E+00
Total for Construction Workers		3.79	7.77	2.11E-07	2.24E-06

10.9.0.2. Mercury and 2,4,6-TNT were determined to be risk drivers for the subsurface soils. Antimony, arsenic, and beryllium were identified as the risk drivers for the groundwater. A waste ash sample contained a TCLP lead concentration which exceeded the regulatory level. Lead was categorized as a COC in the subsurface soils and in the groundwater.

10.9.0.3. In general, the metals and explosives contamination was found in the shallow subsurface soil samples. The highest concentrations appeared to be in the samples in or near the southern disposal mound. The upgradient groundwater sample contained all of the risk driver compounds suggesting an upgradient source contributing to SWMU 54 groundwater quality; however, only the downgradient monitoring well samples contained detectable concentrations of the explosive risk driver compound, HMX. Arsenic, beryllium, and 2,4,6-TNT, which were risk driver compounds in either the subsurface soil or the groundwater, were found in the New River sediment sample collected downstream of the SWMU, indicating contaminant migration.

10.9.0.4. The human health risk assessment indicated a potential for noncarcinogenic and carcinogenic adverse human health effects by the dermal and ingestion exposure scenarios for groundwater and subsurface soils for construction worker and site worker receptors. SWMU 54 is outside of the facility security fence and is accessible from the New River.

SECTION 11

SITE CHARACTERIZATION OF STROUBLES CREEK

11.1 ENVIRONMENTAL SETTING

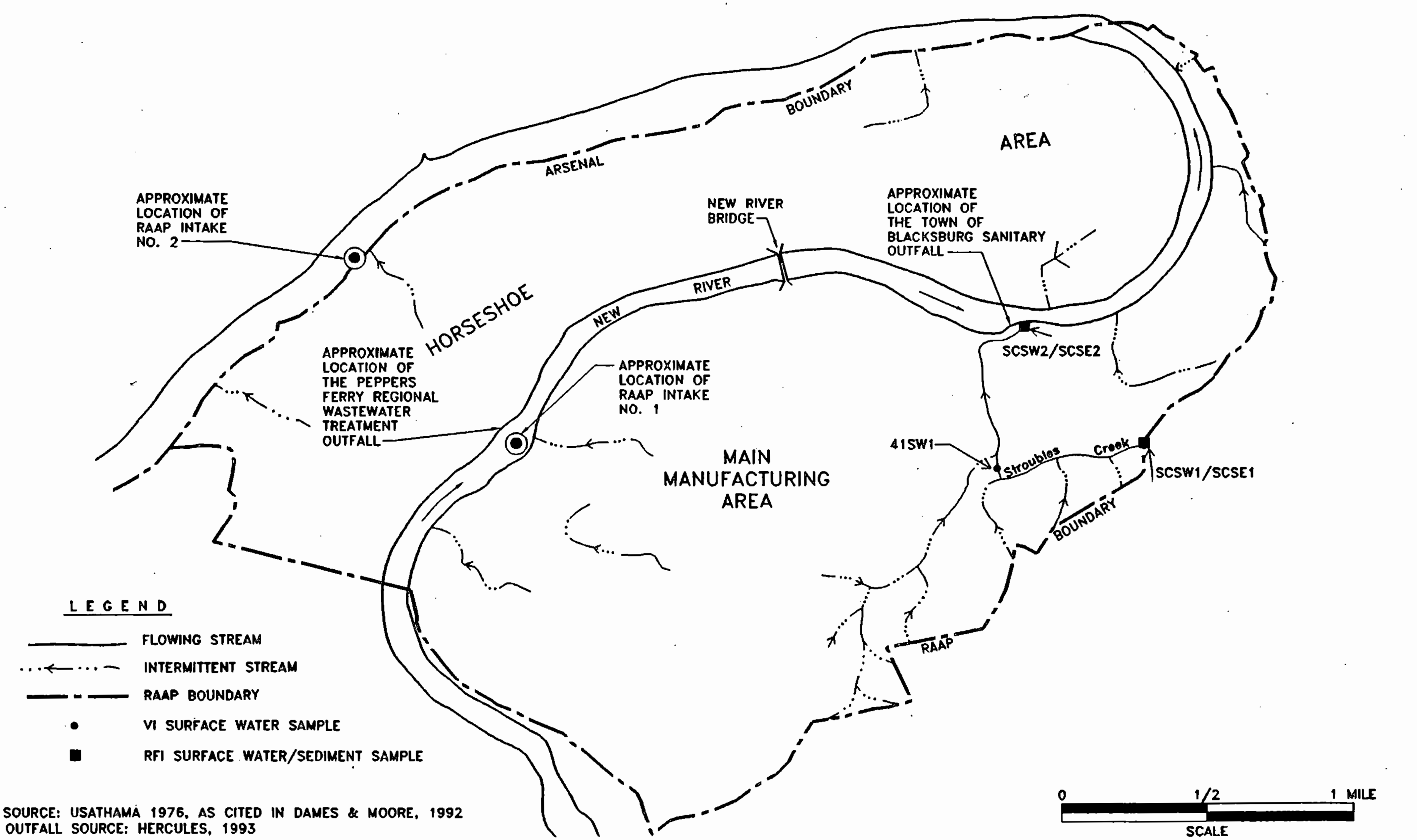
11.1.0.1. Stroubles Creek is the largest local tributary of the New River and flows through the southeast sector of RAAP (Figure 11.1). This creek is fed by several branches that originate on and off the facility. Stroubles Creek consists primarily of stormwater runoff. Groundwater discharging from the karst bedrock may also supply significant stream flow. Prior to entering the facility, branches of Stroubles Creek flow through rural areas and through the City of Blacksburg. The creek empties into the New River within RAAP and contributes significant loading of domestic and industrial wastewater (USATHAMA, 1976). The Blacksburg Municipal Wastewater Treatment Plant discharges approximately 5.7 million gallons per day (mgd) of water into the New River just upstream of where Stroubles Creek empties into the river (Personal Communication, 1995). The Commonwealth of Virginia has classified Stroubles Creek and the portion of the New River passing through the confines of RAAP as water generally satisfactory for beneficial uses; these include, public or municipal water supply, secondary contact recreation, and propagation of fish and aquatic life (USATHAMA, 1976).

11.2 PREVIOUS INVESTIGATIONS

11.2.0.1. A verification investigation (VI) of the Red Water Ash Landfill (SWMU 41) was conducted by Dames & Moore in the Fall of 1991. SWMU 41 is located in the eastern section of the Main Manufacturing Area near a portion of Stroubles Creek. During the VI, one surface water sample was collected from Stroubles Creek at a location approximately 75 feet east of the SWMU 41 lagoon. No other sampling of Stroubles Creek is known to have occurred.

11.2.0.2. Figure 11.1 shows the approximate location of the Stroubles Creek sampling point (41SW1). The SWMU 41 lagoon was an ash disposal unit. Leachate from the lagoon had reportedly been observed along the downslope bank; sample 41SW1 was

FIGURE 11.1
STROUBLES CREEK LOCATION MAP
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



SOURCE: USATHAMA 1976, AS CITED IN DAMES & MOORE, 1992
OUTFALL SOURCE: HERCULES, 1993

2-8 11/20/95

collected at a point where the seep may have entered the creek. The sample was analyzed for metals, explosives, SVOCs, TOC, TOX, and pH.

11.2.0.3. In total, seven metals were detected above the PQLs in the surface water sample (Table 11.1). The metals are common earth elements that were reported at concentrations less than the HBN criteria. One explosive (2,4,6-TNT) was detected in the sample but was reported at a level less than the HBN criterion. The source for the 2,4,6-TNT in the surface water could not be attributed to SWMU 41 since no explosives were detected in any of the on-site samples. Dames & Moore suggested that material in Stroubles Creek or a tributary was adversely impacted when the TNT area was destroyed by the explosion in 1974. TOC and TOX were reported at 6,010 $\mu g/l$ and 82.4 $\mu g/l$. No SVOCs were detected in the creek sample.

11.3 SUMMARY OF RFI FIELD ACTIVITIES

11.3.0.1. Two surface water samples and their associated sediment samples were collected from Stroubles Creek at two locations for the RFI in January 1995. Samples SCSW1 and SCSE1 (surface water and sediment, respectively) were taken at the upstream facility boundary. This location is upstream of all active areas of RAAP. Samples SCSW2 and SCSE2 were taken downstream just prior to Stroubles Creek's discharge to the New River. A duplicate surface water and sediment sample were also collected at this location. Both sampling locations are shown in Figure 11.1. The aqueous samples were analyzed for total metals, explosives, VOCs, SVOCs, TOC, TOX, chloride, and hardness. The sediment samples were analyzed for the same parameters with the exception of chloride and hardness (see Tables 4.3 and 4.4). Field measurements of pH, conductivity, and temperature were also recorded.

11.4 NATURE AND EXTENT OF CONTAMINATION

11.4.0.1. A summary of all positive results (detected compounds) for sediments and surface water of Stroubles Creek is presented in Tables 11.2 and 11.3, respectively. The chemicals of concern (COCs) for Stroubles Creek were determined by the methods discussed in Section 6. This section focuses on those COCs identified as potential human health threats as detailed in the subsequent Risk Assessment subsections.

TABLE 11.1

Summary of Analytical Data For Surface Water Samples Collected At SWMU 41
Radford Army Ammunition Plant, Virginia

SITE ID		41SW1	
FIELD ID		RDWC*76	
S. DATE		10-mar-92	
DEPTH (ft)		0.0	
MATRIX	PQLs	CSW	HBN
UNITS	UGL	UGL	UGL
TAL Inorganics			
BARIUM	20	55.9	1000
CALCIUM	500	58500	NSA
IRON	38.1	199	NSA
MAGNESIUM	500	29300	NSA
MANGANESE	2.75	27.8	3500
POTASSIUM	375	1850	NSA
SODIUM	500	14900	NSA
Explosives			
246TNT	0.635	1.38	11.7
Semivolatiles	NA	None Detected	NSA
Other			
TOTAL ORGANIC CARBON	1000	6010	NSA
TOTAL ORGANIC HALOGENS	1	82.4	NSA
pH	NA	7.99	NSA

Footnotes:

CSW = Chemical surface water.
HBN = Health based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumptions consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
NA = Not available; PQLs are not available for TICs detected in the library scans.
NSA = No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method.
TAL = Target Analyte List.
UGL = Micrograms per liter.

REFERENCE: Dames & Moore, Verification Investigation, August 1992

TABLE 11.2
POSITIVE RESULTS TABLE OF STROUBLES CREEK - Sediment Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	SCSE1	SCSE2	SCSE3 *
METALS (ug/g)			
Arsenic	10.59 J4	9.03 J4	6.70 J4
Lead	13.41 J6	95.87 J6	31.21 J6
Silver	0.03 J4	0.18 J4	0.21 J4
Barium	141.45 J1	240.41 J1	262.41 J1
Beryllium	1.38 J4	1.45 J4	1.39 J4
Chromium	27.80 J6	39.53 J6	36.17 J6
Nickel	32.60 J4	26.99 J4	26.10 J4
SEMIVOLATILES (ug/g)			
Chrysene		0.22	
Di-n-butyl phthalate		7.82 J1	5.53 J1
Fluoranthene		0.27	0.16
Phenanthrene		0.29	0.13
OTHER (ug/g)			
Total Organic Carbon	2841.33	63274.30	43829.80
Extractable Organic Halides (total)	123.00	147.49	141.84

* SCSE3 is a duplicate sample of SCSE2

TABLE 11.3
POSITIVE RESULTS TABLE OF STROUBLES CREEK - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	SCSW1	SCSW2	SCSW3*
METALS (ug/l)			
Barium	44.7 J4	47.3 J4	48 J4
Beryllium	1.95	2.22	2.23
Chromium		30.9 J4	
EXPLOSIVES (ug/l)			
Cyclotetramethylenetetranitramine (HMX)	5.3 J9	5.3 J9	5.3 J9
OTHER (ug/l)			
*TOTAL HARDNESS	148000	152000	153000
*TOTAL ORGANIC CARBON	2690	2490 J7	2370
*TOTAL ORGANIC HALOGENS	16.9	18 J7	16
CHLORIDE	11000	10000	11000

* SCSW3 is a duplicate sample of SCSW2

11.4.1 Nature of Contamination

11.4.1.1 Sediments

11.4.1.1.1. Eleven COCs were identified in the sediments of Stroubles Creek: arsenic, barium, beryllium, chromium (as chromium III), chrysene, di-n-butyl phthalate, fluoranthene, lead, nickel, phenanthrene, and silver. Arsenic and beryllium were considered to pose potential human health risks. Arsenic and beryllium were considered to be the risk drivers for sediment in Stroubles Creek.

11.4.1.1.2. Arsenic was found at 10.59 ug/g in the sample from SCSE1 and at 9.03 ug/g in the sample from SCSE2. A beryllium concentration of 1.38 ug/g was detected in the sample from SCSE1 and 1.45 ug/g in the sample from SCSE2. Barium was detected at 141.45 ug/g in the sample from SCSE1 and at 240.41 ug/g in the sample from SCSE2. Nickel was also found in both sediment samples; SCSE1 contained 32.60 ug/g and SCSE2 contained 26.99 ug/g.

11.4.1.1.3. The other metals categorized as COCs were detected in maximum concentrations as follows: chromium at 39.53 ug/g, lead at 95.87 ug/g, and silver at 0.18 ug/g. All of these results were found in sample SCSE2. Other maximum concentrations of COCs were for SVOcs as follows: chrysene at 0.22 ug/g, di-n-butyl phthalate at 7.82 ug/g fluoranthene at 0.27 ug/g, and phenanthrene at 0.29 ug/g. These SVOCs were only detected in sample SCSE2.

11.4.1.2 Surface Water

11.4.1.2.1. Four COCs were identified for the surface water of Stroubles Creek: barium, beryllium, chromium (as chromium III), and HMX. Of these, only beryllium was categorized as a risk driver. Barium was detected in both samples. The maximum concentration was 47.3 ug/l in SCSW2. Beryllium was also found in both samples; the maximum detection was 2.22 ug/l in SCSW2. HMX was found in both samples at 5.3 ug/l. Chromium was only detected in the SCSW2 sample (30.9 ug/l).

11.4.2 Extent of Contamination

11.4.2.1 Sediment

11.4.2.1.1. Sample SCSE1 was collected upstream from the facility. All of the metals COCs were found in this upstream sample. Arsenic, a risk driver, and nickel were detected at higher levels in this sample than in the downstream sample. None of the SVOC COCs were found in the upstream sample. Upstream from the SCSE1 location, Stroubles Creek has flowed through rural areas and the City of Blacksburg.

11.4.2.1.2. The downstream sample, SCSE2, contained the SVOC COCs, as well as the maximum concentrations of the risk driver beryllium. The upstream barium concentration was 141.45 ug/g and the downstream concentration was 240.41 ug/g. The upstream beryllium concentration was 1.38 ug/g and the downstream concentration was 1.45 ug/g. Downstream lead and silver concentrations were much higher than upstream concentrations, but they were not found at levels considered to pose a potential threat to human health.

11.4.2.2 Surface Water

11.4.2.2.1. The risk driver compound for Stroubles Creek surface water (beryllium), barium, and HMX, were found in both samples. Concentrations of these compounds were at similar levels in both samples. The downstream sample, SCSW2, was the only sample which contained chromium.

11.5 CONTAMINANT FATE AND TRANSPORT

11.5.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. Contaminants detected in Stroubles Creek are subject to transport downstream as dissolved constituents, particulates or suspended solids. Stroubles Creek discharges to the New River within the facility boundaries. Dilution of contaminants, when considering New River receptors downstream of RAAP, will be significant.

11.5.0.2. The source of the explosive COC compound, HMX, in the surface water is not known. Dames & Moore suggested in the previous sampling investigation of Stroubles Creek that residual explosives from the TNT area may have filtered into the creek as a result of the 1974 explosion. However, this would not account for the presence of HMX in the upstream sample. HMX does not show up in the New River samples downstream of the Stroubles Creek sample locations. Explosive compounds are not readily bioaccumulated by living organisms. Explosives are usually transported through the movement of particulates, however, no explosives were found in the associated sediment sample. This may indicate migration to the creek by surface water runoff.

11.5.0.3. Barium and beryllium surface water concentrations are slightly higher in the downstream samples than the upstream ones. However, the difference in concentrations do not suggest that the SWMU 41 ash disposal lagoon has contributed significant amounts of metals to Stroubles Creek. Barium was also found in the New River samples downstream of the Stroubles Creek sample locations.

11.5.0.4. The downstream sediment sample does appear to contain levels of contaminants not present in the upstream sample, particularly SVOCs. When present in sediments, SVOCs tend to remain bound to the soil particles and dissolve slowly into the overlying water. Because of their affinity for organic matter, SVOCs are readily bioaccumulated by living organisms. Barium and beryllium concentrations are higher downstream than upstream. Those metals have also been found in the New River sediments downstream of the Stroubles Creek sample locations. The mobilization of metals would most likely be through suspended sediment.

11.6 RISK ASSESSMENT

11.6.0.1. Stroubles Creek is the largest tributary running into the New River. The creek runs through the RAAP and is largely made up of stormwater run-off. As a result, the water quality of the creek can be greatly affected by on-site operations. Moreover, Stroubles Creek also feeds the New River and has an affect on the surface water and sediment in the river.

11.6.0.2. Future land use in the Stroubles Creek area of the RAAP is uncertain; the area may be used for additional commercial development. It is unlikely that this area will undergo residential development. Consequently, surface water and sediment was analyzed for all current exposure possibilities.

11.6.1 Summary of Chemicals of Potential Concern

11.6.1.1. The chemicals considered in the risk evaluation for sediment at Stroubles Creek include 7 metals (arsenic, barium, beryllium, chromium III, lead, nickel, and silver) and 4 semivolatiles (chrysene, di-n-butyl phthalate, fluoranthene, and phenanthrene).

11.6.1.2. The chemicals considered in the risk evaluation for surface water at Stroubles Creek include 3 metals (barium, beryllium, and chromium III), and one explosive (HMX).

11.6.1.1 Comparison to ARARs and TBCs for Groundwater and Soils

11.6.1.1.1. Groundwater in the vicinity of RAAP is not used for drinking water serving more than 25 people and therefore MCLs and MCLGs are not considered as ARARs for Stroubles Creek. In addition, there are no federal or Commonwealth of Virginia standards relating chemical concentrations in soils to toxic effects on vegetation or wildlife. TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995a).

11.6.2 Exposure Assessment

11.6.2.1 Potential Pathways and Receptors

11.6.2.1.1. Current exposure pathways considered at Stroubles Creek are site workers, construction workers, fishermen, and other recreational users of the creek. The remaining potential receptors have a low probability of completion and therefore, are not quantified for current receptors (area residents). Stroubles Creek runs through the RAAP and public access is allowed to recreational users of surface water in the area. Current routes of human exposure which were considered for Stroubles Creek include ingestion, and dermal exposure to potentially contaminated surface water and sediment through the uses described above.

11.6.2.1.2. The conceptual site model summary for Stroubles Creek is presented in Figure 11.2 and includes exposure routes, potential receptors and the medium containing the potential contaminants of concern. All chemicals not eliminated by data validation were considered in the risk assessment for this SWMU.

11.6.2.2 Exposure Point Concentrations and Chronic Daily Intakes

11.6.2.2.1. Exposure point concentrations for the chemicals of concern evaluated for Stroubles Creek are listed in the tables in Appendix I. These concentrations range from 0.00208 mg/L (beryllium) to 0.046 mg/L (barium) in surface water and 0.066 mg/kg (chrysene) to 184 mg/kg (barium) in sediment.

11.6.3 Risk Characterization

11.6.3.0.1. The carcinogenic risk and hazard indices were calculated for the surface water ingestion and dermal contact pathways. These calculations are presented in Appendix I. The calculated hazard indices for the sediment pathway exposure through dermal contact are below risk levels for CT and RME receptors. Moreover, the hazard indices for the surface water pathway exposure through ingestion amd dermal contact are below risk levels for both receptor groups. The cancer risk numbers are also outside the USEPA target risk range of 1 x 10^{-4} to 1 x 10^{-6} by at least one order of magnitude for the CT. For a few exposure scenarios, the cancer risk values are with the USEPA's target range for RME receptors. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

11.6.3.1 Non-carcinogenic Effects

11.6.3.1.1. The calculated hazard indices for the current site worker exposure to surface water through ingestion and dermal contact scenarios are below acceptable risk levels. The hazard indices calculated for the current site worker exposure to sediment through ingestion and dermal contact scenarios are also below acceptable risk levels for both CT and RME receptors.

Figure 11.2
Conceptual Site Model for Current and Future Exposure Pathways
Stroubles Creek
Radford Army Ammunition Plant
Radford, Virginia

				Current Receptors				Future Receptor
Primary Source	Release Mechanism	Receiving Medium	Exposure Route	Site Workers	Rec. Users	Hunters, Fisherman	Const. Workers	Site Workers
RAAP Activities	Surface Runoff/ Groundwater Discharge	Surface Water and Sediment	Ingestion	X	X	X(F)	X	
			Inhalation					
			Dermal	X	X	X(F)	X	
	Tracking Deposition	Surficial Soils	Ingestion					
			Inhalation					
			Dermal					
	Leaching/ Deposition	Subsurface Soils	Ingestion					
			Inhalation					
			Dermal					
	Uptake	Biota	Ingestion					
	Leaching	Groundwater	Ingestion					
			Inhalation					
			Dermal					

X = Pathways of potential concern
F = Fisherman scenario

11.6.3.1.2 The hazard indices for current recreational user of surface water do not exceed acceptable risk levels for either of the exposure scenarios (ingestion or dermal contact) analyzed for Stroubles Creek.

11.6.3.1.3 The calculated hazard index for the fisherman exposure to surface water through dermal contact at Stroubles Creek does not exceed acceptable levels for RME or CT receptors. The hazard index for fisherman exposure to surface water through ingestion also does not exceed acceptable risk levels at Stroubles Creek for either receptor group.

11.6.3.1.4. The calculated hazard indices for the construction worker exposure scenario to surface water through ingestion or dermal contact at Stroubles Creek do not exceed acceptable levels for both CT and RME receptors.

11.6.3.2 Carcinogenic Effects

11.6.3.2.1. The calculated cancer risks for the current site worker exposure to surface water through ingestion and dermal contact scenarios are below USEPA target risk range. The calculated cancer risks for the current site worker exposure to sediment through dermal contact scenario are within USEPA target risk range due to the presence of beryllium and arsenic for RME receptors. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are below the USEPA target range for cancer risk. Current site worker exposure to sediment through ingestion scenario also exhibits elevated cancer risks for Stroubles Creek for RME receptors. However, the cancer risk is within the USEPA target range due to the presence of arsenic and beryllium in the sediment.

11.6.3.2.2. The calculated cancer risks for the current recreational user exposure to surface water through dermal contact and ingestion scenarios are below USEPA target risk range for acceptable cancer risks levels for these exposure scenarios at Stroubles Creek.

11.6.3.2.3. The calculated cancer risk for the current fisherman exposure to surface water through dermal contact scenario is above the USEPA target risk range for RME receptors due to the presence of beryllium. All other chemicals of concern evaluated do not exhibit an increased cancer risk due to a lack of toxicity information or because they are within the USEPA target range for cancer risk. The cancer risks for current fisherman exposure to surface water through ingestion scenario are below the USEPA target range for cancer risk.

11.6.3.2.4. The calculated cancer risks for the construction worker exposure to surface water through ingestion and dermal contact scenarios are below USEPA target risk range for RME and CT receptors.

11.6.4 Uncertainty Analysis

11.6.4.0.1. Data collection/evaluation uncertainty may be relevant at Stroubles Creek due to the types and numbers of samples collected. Many metals detected at this site in surface water and sediment are naturally occurring and no analysis was accomplished to differentiate between site-related and non-site-related concentrations. In this case, all metals detected in sediment and surface water were retained as if they were site-related. The calculations have shown to present unacceptable risks due to these metals and this could be an overestimate due to natural metals concentration in surface water and sediments.

11.6.4.0.2. One of the main areas of uncertainty is in exposure assessment as relates to determining future land uses at a contaminated site. The majority of the land at RAAP is commercial or industrial to support the explosives manufacturing process, with few scattered residential communities located in Montgomery and Pulaski counties. Access to the Stroubles Creek within RAAP is restricted, and therefore a current residential exposure scenario is unlikely. For the purpose of assessing risk, future land use was assumed to be industrial.

11.6.4.0.3. Another area of uncertainty in evaluating human health risk from Stroubles Creek is toxicity assessment. Oral and dermal slope factors are not available for seven of the nine metals which were detected in groundwater, including lead. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

11.6.4.0.4. For the chemicals detected in surface water at Stroubles Creek, an exposure scenario was evaluated for fishermen ingesting contaminated fish. This was accomplished using USEPA (1989) standard default exposure values and calculating an expected concentration in fish due to uptake. As with all modeled concentrations, there is a degree of uncertainty associated with these calculations and assumptions. Only chromium III could be quantified in this manner due to the lack of information concerning bioconcentration of the other detected chemicals. This may tend to underestimate the risk for this exposure scenario at Stroubles Creek.

11.7 RISK SUMMARY

11.7.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for current site worker, current fisherman, current recreational, and current construction worker receptors potentially exposed to multiple chemicals in surface water and sediment during use. The surface water pathway calculations were summarized and are presented in Table 11.4. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 1×10^{-4} to 1×10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index below one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

11.7.0.2 . At Stroubles Creek, no pathway presents a total hazard index for the creek of greater than one. The total cancer risk values for one exposure scenario was in the USEPA target risk range (site worker RME). Total cancer risks for fishermen (RME) were above the USEPA target risk range. Consequently, these values indicate low potential for noncarcinogenic and a greater potential for carcinogenic adverse human health effects for exposure to surface water or sediment at Stroubles Creek.

Table 11.4
Summary of Human Health Risk
Stroubles Creek
Radford Army Ammunition Plant

Receptor	Pathways	HI		Cancer Risk	
		CT	RME	CT	RME
Site Worker	Ingestion of Surface Water	0	0	3.13E-08	3.13E-07
	Dermal Contact with Surface Water	0	0	7.88E-09	1.06E-07
	Ingestion of Sediment	0	0.01	7.25E-08	1.45E-06
	Dermal Contact with Sediment	0	0	3.69E-07	4.97E-06
Total for Site Worker		0	0.01	4.81E-07	6.84E-06
Fisherman	Ingestion of Surface Water	0	0	7.20E-10	1.44E-07
	Dermal Contact with Surface Water	0	0	4.55E-07	1.18E-04
Total for Fisherman		0	0	4.56E-07	1.18E-04
Construction Worker	Ingestion of Surface Water	0	0	1.56E-08	1.25E-07
	Dermal Contact with Surface Water	0	0	2.96E-08	1.54E-07
Total for Construction Workers		0	0	4.52E-08	2.79E-07
Recreational User	Ingestion of Surface Water	0	0	8.78E-11	5.78E-09
	Dermal Contact with Surface Water	0	0	3.41E-09	2.63E-07
Total for Recreational User		0	0	3.50E-09	2.69E-07

11.8 STROUBLES CREEK SUMMARY

11.8.0.1. Stroubles Creek flows through the southeast section of RAAP; it is the largest local tributary of the New River. Upstream of the facility, Stroubles Creek flows through the City of Blacksburg. Two surface water and sediment samples, upstream of RAAP and downstream at the point of discharge to the New River, were collected to help characterize the creek.

11.8.0.2. Arsenic and beryllium were determined to be the risk driver compounds for Stroubles Creek sediments. Several SVOCs were categorized as COCs for the sediments. Beryllium was determined to be the risk driver compound for the surface water.

11.8.0.3. The upstream sediment sample contained all the metals COCs and higher levels of arsenic and nickel than the downstream sample, but no SVOCs. The downstream sediment sample contained all of the SVOCs detected in the creek and the maximum concentration of one of the sediment risk driver compounds. Beryllium was detected in both the upstream and downstream surface water samples.

11.8.0.4. The human health risk assessment indicated a potential for carcinogenic adverse human health effects for ingestion and dermal contact of sediments for site workers, and for dermal contact with surface water for fishermen. Both sample locations were within the fenced facility boundary, and were therefore from areas of the creek which have limited public access.

SECTION 12

SITE CHARACTERIZATION OF THE NEW RIVER

12.1 ENVIRONMENTAL SETTING

12.1.0.1. The New River is the most significant surface water feature within RAAP. The facility is built within and adjacent to a prominent meander loop of this river. Within RAAP, the river width varies from 200 to 1,000 feet, but averages approximately 400 feet. The river flow varies due to water management at Claytor Dam, approximately 9 miles upgradient (south) from RAAP. Downstream from the Claytor Dam, typical flows of the New River range between 3,200 and 8,000 million gallons per day (mgd). During typical flow conditions, the depth is approximately 4 to 6 feet; however, pools may be 10 feet deep. There are 13 miles of river shoreline within the RAAP boundaries.

12.1.0.2. The headwaters of the New River are in northwestern North Carolina, near the Tennessee state line. In the vicinity of RAAP, the New River flows northwesterly cutting cliffs through the bedrock. The path of the New River, which is generally perpendicular to the ridge lines of the Valley and Ridge province, indicates that the river existed prior to the Paleozoic folding of these rocks. In some areas, this river has eroded 4000 feet of rock. During the Paleozoic, the erosion rate of the river was higher than the uplift rate of the rocks. This produced the entrenched river channel present today. The New River is perhaps the oldest river in North America, estimated to be 350 million years old.

12.1.0.3. All water used at RAAP is taken from the New River. Separate water systems are provided for the Main Manufacturing Area and the Horseshoe Area. Intake No. 1 is located approximately 2 miles upstream of the mouth of Stroubles Creek. Intake No. 2 is located approximately 6 miles downstream of the mouth of Stroubles Creek (Figure 3.11). Upstream of RAAP, the New River serves as a source of drinking water for the towns of Blacksburg and Christiansburg.

12.1.0.4. Both industrial and domestic wastewaters are discharged into the New River from the Peppers Ferry Regional Wastewater Treatment Plant (PFWWTP). This discharge is located within the boundaries of RAAP, just downstream from intake No. 1. Until 1987, the city of Radford provided only primary sewage treatment before discharging 2.5 mgd into the New River (USATHAMA, 1976). Secondary treatment is now provided at the PFWWTP. Currently this plant discharges approximately 4.5 mgd of water into the New River (Personal Communication, 1995).

12.1.0.5. RAAP discharges approximately 25 mgd at fifteen industrial wastewater outfalls along the New River and Stroubles Creek under VPDES permit number VA0000248. The effluent consists of various treated process water, wash water, cooling water, run off, sanitary wastewater, and stormwater. The approximate locations of the discharge outfalls are shown in Figure 3.11. For internal use and reference, RAAP has identified a total of 135 outfalls to either the New River or Stroubles Creek from the Main Manufacturing and Horseshoe Areas. These outfalls discharge stormwater, spring-fed groundwater, and minor amounts of steam condensate.

12.1.0.6. The upper reaches of the New River and its tributaries have water of excellent quality. These streams have less than 50 parts per million (ppm) of dissolved solids due to the underlying metamorphic rocks, which contribute very little to natural pollution. In the balance of the region, dissolved solids increase to the 50-199 ppm range as water drains from areas underlain by shale, sandstone, and limestone formations. Where carbonate rocks occur, the bicarbonate content of the water is particularly high, resulting in 100-199 ppm of calcium carbonate ($CaCO_3$) found in the waters of Walker Creek, Sinking Creek, Wolf Creek, and the New River downgradient of RAAP (Figure 2.2).

12.2 PREVIOUS INVESTIGATIONS

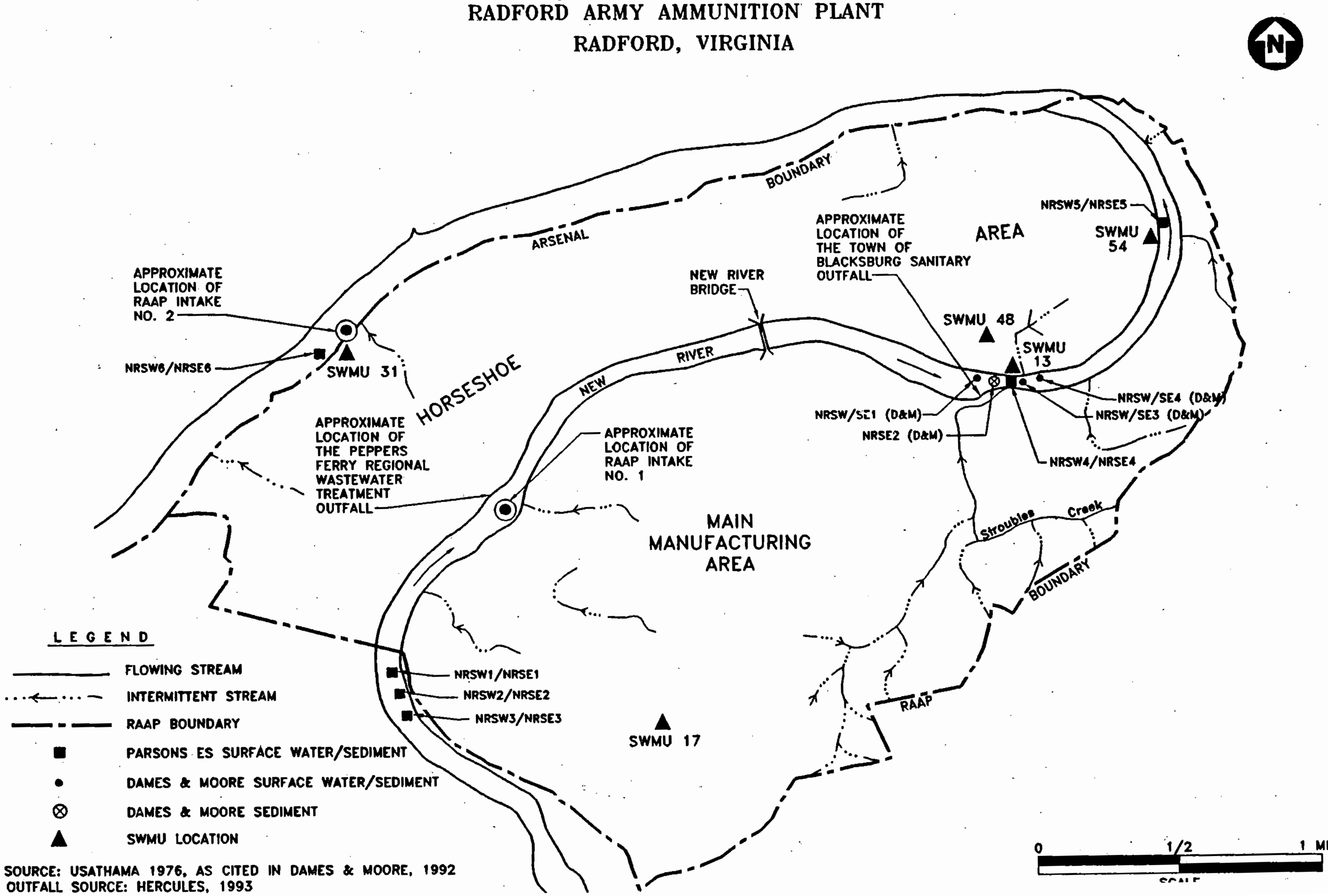
12.2.0.1. In July 1994, fish, clam, sediment and water samples were collected from the New River and analyzed for the propellant ingredients 2,4-DNT and 2,6-DNT (USAEHA, 1994). The samples were collected along the shoreline that receives RAAP discharge. The samples included 12 sediment and water samples, 5 composite clam samples, and 5 composite fish samples. There was no 2,4-DNT or 2,6-DNT detected in the sediment samples. There was no 2,6-DNT detected in any fish or clam samples. However, low levels of 2,4-DNT was detected at two sampling sites for clams (0.07 mg/kg and 0.0093 mg/kg) and one sampling site for fish (0.0081 mg/kg). These levels were determined to be well below the concentration required to exceed the reference dose for 2,4-DNT. No 2,6-DNT was detected in any of the water samples. 2,4-DNT was detected below outfall 29 (Figure 3.11) to a point about 2 miles downstream at 6 discrete sampling locations. For the water samples, 2,4-DNT was observed in the range of 0.11-2.4 μg/l. These levels are well below the 100 μg/l drinking water advisory and the 113 μg/l discharge permit requirements.

12.2.0.2. A RCRA Facility Investigation (RFI) of the Waste Propellant Burning Ground (SWMU 13) was conducted by Dames & Moore in the Fall of 1991. SWMU 13 is a unit where active burning of waste explosives, propellants, and laboratory wastes is conducted. It is situated on a bank of the New River within the 100-year flood plain. As part of the RFI, Dames & Moore collected three surface water samples and their associated sediments from the New River. Additionally, one sediment sample with no associated surface water sample was obtained

12.2.0.3. Figure 12.1 shows the approximate location of SWMU 13 and the surface water and sediment samples collected during the RFI. The New River samples were from up-river, adjacent, and down-river locations in areas predicted to be most impacted by contaminants migrating from SWMU 13 groundwater. The samples were analyzed for TAL metals, explosives, VOCs, and SVOCs.

12.2.0.4. The analytical results of the four sediment samples are presented in Table 12.1. In the sediment samples, arsenic, beryllium, cobalt and lead concentrations exceeded HBNs. Concentrations of arsenic and cobalt were less than half the background comparison criteria for alluvial soils. Beryllium was detected only once, at a concentration less than 5 percent greater than the comparison criterion. Lead was detected at a concentration 2 percent above the HBN in NRSE3, but at a concentration less than the background comparison criterion. According to Dames & Moore, even though lead concentrations are anomalously high in SWMU 13 soils, the lead concentrations in the four New River samples are essentially the same as the five background alluvial soil samples collected from New River alluvium off-post. No explosives or VOCs were detected in the four New River sediment samples. Five SVOCs were detected in the downgradient sample NRSE4, but each SVOC was detected at concentrations less than their respective HBNs. Two SVOCs are phthlates and three SVOCs are likely fuel related.

FIGURE 12.1
NEW RIVER LOCATION MAP
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA



SOURCE: USATHAMA 1976, AS CITED IN DAMES & MOORE, 1992
OUTFALL SOURCE: HERCULES, 1993

G2-7 11/20/95

TABLE 12.1

Summary of Analytical Data For Sediment Samples Collected At SWMU 13
Radford Army Ammunition Plant, Virginia

SITE ID		NRSE1	NRSE2	NRSE3	NRSE3D	NRSE4	
FIELD ID		RDSE*1	RDSE*2	RDSE*3	RDSE*7	RDSE*4	
S. DATE		16-apr-92	16-apr-92	16-apr-92	16-apr-92	16-apr-92	
DEPTH (ft)		1.0	1.0	1.0	1.0	1.0	
MATRIX	PQLs	CSE	CSE	CSE	CSE	CSE	HBN
UNITS	UGG	UGG	UGG	UGG	UGG	UGG	UGG
TAL Inorganics							
ALUMINIUM	14.1	2910	2250	4520	NT	7860	230000
ARSENIC	30	[2.29]	[1.86]	[2.86]	NT	[2.67]	0.5
BARIUM	1	37.8	40	54.9	NT	112	1000
BERYLLIUM	0.2	LT 0.5	LT 0.5	LT 0.5	NT	[0.943]	0.1
CALCIUM	100	1200	558	1180	NT	2120	NSA
CHROMIUM	4	16.9	10.1	12.3	NT	21.3	400
COBALT	3	[4.15]	[3.9]	[5.27]	NT	[10]	0.8
COPPER	7	8.88	7.14	29.8	NT	15.9	2900
IRON	1000	32200	20900	18600	NT	29500	NSA
LEAD	2	113	62.9	[204]	NT	136	200
MAGNESIUM	50	1210	751	1810	NT	2870	NSA
MANGANESE	0.275	414	376	193	NT	1250	8000
NICKEL	3	5.98	5	8.55	NT	10.7	1000
POTASSIUM	37.5	388	282	673	NT	1250	NSA
SODIUM	150	162	138	226	NT	264	NSA
VANADIUM	0.775	14.3	11.4	16.1	NT	27.8	560
ZINC	30.2	447	272	374	NT	414	16000
Explosives (a)	NA	None Detected	None Detected	None Detected	None Detected	None Detected	NSA
Volatiles (a)	NA	None Detected	None Detected	None Detected	None Detected	None Detected	NSA
Semivolatiles							
BIS(2-ETHYLHEXYL) PHTHALATE	0.3	2.94	LT 0.62	1.62	NT	15.5	50
DI-N-BUTYL PHTHALATE	0.3	LT 0.061	LT 0.061	LT 0.061	NT	1.96	1000
FLUORANTHENE	0.3	LT 0.068	LT 0.068	LT 0.068	NT	0.16	500
PHENANTHRENE	0.5	LT 0.033	LT 0.033	LT 0.033	NT	0.089	40

TABLE 12.1 (Cont'd)

SITE ID		NRSE1	NRSE2	NRSE3	NRSE3D	NRSE4	
FIELD ID		RDSE*1	RDSE*2	RDSE*3	RDSE*7	RDSE*4	
S. DATE		16-apr-92	16-apr-92	16-apr-92	16-apr-92	16-apr-92	
DEPTH (ft)		1.0	1.0	1.0	1.0	1.0	
MATRIX	PQLs	CSE	CSE	CSE	CSE	CSE	HBN
UNITS (#)	UGG	UGG	UGG	UGG	UGG	UGG	UGG
Semivolatile TICs							
CYCLOHEXENE OXIDE	NA	0.39 S	0.388 S	ND	NT	ND	NSA
TOTAL UNKNOWN TICs	NA	ND	(7)20.3	(2)17.2	NT	ND	NSA

Footnotes :

C = Indicates that analysis was confirmed using a second column.
CSE = Chemical sediment.
HBN = Health based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumptions consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
LT = Concentration is reported as less than the certified reporting limit.
NA = Not available; PQLs are not available for TICs detected in the library scans.
ND = Analyte was not detected.
NSA = No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
NT = Not tested; parameters were not tested (included) in the sample analyses.
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
S = Results are based on an internal standard; flag is used for TICs detected in library scans.
TAL = Target Analyte List.
TICs = Tentatively identified compounds that were detected in the GC/MS library scans.
UGG = Micrograms per gram.
(a) = Level 2 Data.
( ) = Parenthesis are used to indicate the number of unknown TICs that were detected in either the volatile or semivolatile GC/MS library scans. The number beside the parenthesis is the total concentration of all TICs detected in each respective scan.
[ ] = Brackets indicate that the detected concentration exceeds the HBN.

SOURCE: DAMES & MOORE, DRAFT RCRA FACILITY INVESTIGATION, SEPT 1992

12.2.0.5. The analytical results of the three surface water samples are presented in Table 12.2. Nine TAL metals were detected, but of the four metals with established HBNs, none were found at concentrations exceeding the HBN. No explosives or SVOCs were detected in any samples. Carbon disulfide (a VOC) was detected in samples NRSW1 and NRSW3 at concentrations less than one percent of the HBN. Carbon disulfide has not been associated with the contaminants found at SWMU 13.

12.3 SUMMARY OF RFI FIELD ACTIVITIES

12.3.0.1. Six surface water samples and their associated sediment samples were collected in July 1995 from the New River at various points for the Parsons ES RFI. The locations are shown in Figure 12.1. The samples were generally collected from locations up-river of the facility or at the potential entry point of contaminants from the four SWMUs addressed in this report. In some cases, the sample locations were in areas where the river was likely to be impacted by more than one SWMU. The sediment samples were analyzed for total metals, explosives, VOCs, SVOCs, TOC, and TOX. The surface water samples were analyzed for the same parameters plus chloride and hardness (see Tables 4.3 and 4.4). Field measurements of pH, conductivity, and temperature were also recorded.

12.3.0.2. Samples NRSW1, NRSW2, and NRSW3 (and their associated sediment samples NRSE1, NRSE2, and NRSE3) were collected up-river of the facility. Samples NRSW4/NRSE4 were taken at an area down-river of SWMU 48, in the general vicinity of SWMU 13. Samples NRSW5/NRSE5 were collected down-river of SWMU 54, and samples NRSW6/NRSE6 were taken down-river of SWMU 31. The locations of the river samples associated with SWMUs 48, 54, and 31 are also shown on the SWMU sample location maps (Figures 9.2, 10.2, and 8.2, respectively) for better scale. A duplicate of NRSW5/NRSE5 was collected for QA/QC purposes. Table 12.3 presents a summary of the field activities conducted on the New River for this RFI.

TABLE 12.2
Summary of Analytical Data For Surface Water Samples Collected At SWMU 13
Radford Army Ammunition Plant, Virginia

SITE ID		13SW1	NRSW1	NRSW3	NRSW3D	NRSW4	
FIELD ID		RDWA*11	RDSW*1	RDSW*2	RDSW*4	RDSW*3	
S. DATE		15-jan-92	16-apr-92	16-apr-92	16-apr-92	16-apr-92	
DEPTH (ft)		0.0	0.0	0.0	0.0	0.0	
MATRIX	PQLs	CSW	CSW	CSW	CSW	CSW	HBN
UNITS	UGL	UGL	UGL	UGL	UGL	UGL	UGL
TAL Inorganics							
ALUMINIUM	141	47500	168	LT 141	NT	LT 141	101500
ARSENIC	10	2.99	LT 2.54	LT 2.54	NT	LT 2.54	50
BARIUM	20	495	22.8	18.6	NT	19.2	1000
CALCIUM	500	22200	16100	13600	NT	13600	NSA
CHROMIUM	10	[78.8]	LT 6.02	LT 6.02	NT	LT 6.02	50
COBALT	70	[30.6]	LT 25	LT 25	NT	LT 25	0.35
COPPER	60	143	LT 8.09	LT 8.09	NT	LT 8.09	1295
IRON	38.1	59700	416	217	NT	170	NSA
LEAD	10	[500]	1.95	2.06	NT	2.39	50
MAGNESIUM	500	12400	6190	5230	NT	5320	NSA
MANGANESE	2.75	1940	62.4	22.1	NT	11	3500
NICKEL	50	43.8	LT 34.3	LT 34.3	NT	LT 34.3	700
POTASSIUM	375	13600	2130	2400	NT	2360	NSA
SODIUM	500	1830	7630	5220	NT	5300	NSA
VANADIUM	40	89.9	LT 11	LT 11	NT	LT 11	245
ZINC	50	893	LT 21.1	LT 21.1	NT	LT 21.1	7000
Explosives (a)							
135TNB	0.449	1.18	LT 0.611	LT 0.611	LT 0.611	LT 0.611	1.75
246TNT	0.635	[32.9]	LT 0.635	LT0.635	LT0.635	LT0.635	11.7
24DNT	0.064	[15.8]	LT 0.064	LT 0.064	LT 0.064	LT 0.064	0.05
26DNT	0.074	[3.71]	LT 0.074	LT 0.074	LT 0.074	LT 0.074	0.051
HMX	1.21	12.8	LT 1.21	LT 1.21	LT 1.21	LT 1.21	1750
Volatiles (a)							
CARBON DISULFIDE	0.5	LT 0.50	24	2.3	LT 0.50	LT 0.50	4000

SOURCE: DAMES & MOORE DRAFT RCRA

TABLE 12.2 (Cont'd)

SITE ID		13SW1	NRSW1	NRSW3	NRSW3D	NRSW4	
FIELD ID		RDWA*11	RDSW*1	RDSW*2	RDSW*4	RDSW*3	
S. DATE		15-jan-92	16-apr-92	16-apr-92	16-apr-92	16-apr-92	
DEPTH (ft)		0.0	0.0	0.0	0.0	0.0	
MATRIX	PQLs	CSW	CSW	CSW	CSW	CSW	HBN
UNITS (#)	UGL	UGL	UGL	UGL	UGL	UGL	UGL
Semivolatiles							
24DNT	10	[13.6]	LT 4.5	LT 4.5	NT	LT 4.5	0.05
26DNT	10	[2.39]	LT 0.79	LT 0.79	NT	LT 0.79	0.051
Semivolatile TICs							
1,1,2,2-TETRACHLOROETHANE	NA	6 S	ND	ND	NT	ND	NSA
1,1,2-TRICHLOROETHANE	NA	6 S	ND	ND	NT	ND	NSA
TOTAL UNKNOWN TICs	NA	(1)10	(1)7	ND	NT	ND	NSA
Other							
NITRITE,NITRATE	100	530	NT	NT	NT	NT	10000
TOTAL ORGANIC CARBON	1000	12	NT	NT	NT	NT	NSA
TOTAL ORGANIC HALOGENS	1	33.5	NT	NT	NT	NT	NSA
pH	NA	7.68 K	NT	NT	NT	NT	NSA

SOURCE: DAMES & MOORE, DRAFT RCRA FACILITY INVESTIGATION, SEPT 1992

TABLE 12.2 (Cont'd)

Footnotes :

CSW = Chemical surface water.
HBN = Health based number as defined in the RCRA permit. HBNs not specified in the permit were derived using standard exposure and intake assumptions consistent with EPA guidelines (51 Federal Register 33992, 34006, 34014, and 34028).
K = Indicates holding time for extraction and preparation was not met, but data quality is not believed to be affected.
LT = Concentration is reported as less than the certified reporting limit.
NA = Not available; PQLs are not available for TICs detected in the library scans.
ND = Analyte was not detected.
NSA = No standard (HBN) available; health effects data were not available for the calculation of a HBN. HBNs were not derived for TICs.
NT = Not tested; parameters were not tested (included) in the sample analyses.
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method.
S = Results are based on an internal standard; flag is used for TICs detected in library scans.
TAL = Target Analyte List.
TICs = Tentatively identified compounds that were detected in the GC/MS library scans.
UGL = Micrograms per liter.
(a) = Level 2 data.
( ) = Parenthesis are used to indicate the number of unknown TICs that were detected in either the volatile or semivolatile GC/MS library scans. The number beside the parenthesis is the total concentration of all TICs detected in each respective scan.
[ ] = Brackets indicate that the detected concentration exceeds the HBN.

SOURCE: DAMES & MOORE, DRAFT RCRA FACILITY INVESTIGATION, SEPT 1992

TABLE 12.3

SUMMARY OF NEW RIVER RFI FIELD ACTIVITIES

RADFORD ARMY AMMUNITION PLANT

Area	Surface Water Sampled*	Sediment Sampled	Comments
New River	NRSW1	NRSE1	Up-river of facility
	NRSW2	NRSE2	Up-river of facility
	NRSW3	NRSE3	Up-river of facility
	NRSW4	NRSE4	Down-river of SWMU 48
	NRSW5	NRSE5	Down-river of SWMU 54
	NRSW6	NRSE6	Down-river of SWMU 31
	NRSW8	NRSE8	Duplicate of NRSW5/NRSE5

* Field measurements of pH, temperature, and conductivity were also recorded.

12.4 NATURE AND EXTENT OF CONTAMINATION

12.4.0.1. The positive results (detected compounds) for sediment and surface water samples collected from the New River are shown in Tables 12.4 and 12.5, repectively. The spring sample (SPG3SE/SW1) has been discussed as part of the SWMU 17 (Vicinity) section because of the identified hydraulic connection with SWMU 17. However, the analytical results have been presented here because of the proximity of the spring to the New River and the potential for the results to be impacted by the river (SPG3SE/SW1 was not sampled for all the same parameters as the river samples).

12.4.0.2. In order to assess the results statistically, three samples were collected upstream (background) of RAAP. Statistical analysis was performed to determine if the downstream results were significantly different from upstream of the facility. Those compounds not detected at levels greater than the background distribution were not considered further. Those compounds which were not detected in the background samples were analyzed from a risk assessment perspective and are included in the following discussion.

12.4.0.3. The statistical analysis was performed using a tail area probability calculation in the tail area probability calculation, a specific sampling point is compared to the background distribution, and the percentage of the background distribution falling below the sampling point is determined. The null hypothesis is that less than 95% of the background distribution will fall below the sampling point; if this is true, then the sample will be considered to be "within" the background distribution. Conversely, the alternate hypothsis is that more than 95% of the background distribution falls below the sample value; if this is true, then the sample will be considered to be different than background. This concept can be understood simply as determining where the sample value lies relative to the background distribution. For example, if 50% of the background distribution lies below the sample value, then the sample value is in the exact middle of the background distribution and the sample is considered to be "in" the background distribution; if, however, 95% of the background distribution lies below the sample value, then the sample is not in the background distribution.

12.4.0.4. A Tail Area Probability value was calculated for each sample for each analyte which had a positive hit in the background sample; if all background samples were

TABLE 12.4
POSITIVE RESULTS TABLE OF NEW RIVER - Sediment Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	NRSE1	NRSE2	NRSE3	NRSE4	NRSE5	NRSE6	NRSE8*	SPG3SE1
METALS (ug/g)								
Arsenic					6.92		7.83	17.40 J4
Selenium			1.85					
Lead	148.42 J1	136.29 J1	200.00 J1	4415.58	220.08 J1	141.99 J1	245.90 J1	548.59 J6
Silver	0.14	0.09	0.15	0.10	0.10	0.11	0.07	0.22 J4
Barium	226.35 J1	151.82 J1	415.00 J1	97.14	178.82 J1	109.77 J1	187.16 J1	700.63 J1
Beryllium			3.03	0.99	1.31		1.31	4.23 J4
Chromium	46.20 J1	32.01 J1	77.33 J1	37.53	31.50 J1	24.89 J1	33.88 J1	62.70 J6
Nickel	25.05	15.72	41.83	13.25	15.82	12.49	14.89	52.98 J4
Mercury								0.13 J4
SEMIVOLATILES (ug/g)								
Bis (2-ethylhexyl) phthalate				6.62				
Diethyl phthalate				6.23				
Dimethyl phthalate				8.31				
Di-n-butyl phthalate				12.99				
Benzo[a]anthracene	0.58	0.32	0.72			0.40		
Chrysene	1.67	0.35	0.68			0.53		
Fluoranthene		0.30	0.80	0.08		0.50		
Phenanthrene	0.76	0.51	0.82			0.35		
Pyrene	0.80	0.40	1.00			0.76		
N-Nitrosodiphenylamine				2.60				
EXPLOSIVES (ug/g)								
2,4,6-Trinitrotoluene					28.89 J10			
OTHER (ug/g)								
Total Organic Carbon	91651.20	58478.60	36333.30	9831.17	11251.70	22595.40	20218.60	33742.00
Extractable Organic Halides (tot	185.53	158.48	166.67	129.87	82.53	152.67	81.97	244.40

* NRSE8 is a duplicate sample of NRSE5

TABLE 12.5
POSITIVE RESULTS TABLE OF NEW RIVER - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	NRSW1	NRSW2	NRSW3	NRSW4	NRSW5	NRSW6	NRSW8*	SPG3SW1
METALS (ug/l)								
Lead				9.80				25.20
Barium	24.90	25.10	24.90	26.30	21.10	24.80	21.10	26.60 J4
Beryllium								1.64
VOLATILES (ug/l)								
Methylene chloride								
OTHER (ug/l)								
Total Hardness	42700.00	42800.00	43200.00	44600.00	47800.00	51300.00	47700.00	
Total Organic Carbon	2180.00	2320.00	2080.00	1960.00	1810.00	2310.00	1870.00 J7	1200.00
Total Organic Halogens				10.00				
Chloride	3890.00	3750.00	3810.00	3950.00	4030.00	4120.00	4000.00	

* NRSW8 is a duplicate sample of NRSW5

TABLE 12.5
POSITIVE RESULTS TABLE OF NEW RIVER - Aqueous Samples
RADFORD ARMY AMMUNITION PLANT

Field Sample Number	NRSWTB	NRSWTB2
METALS (ug/l)		
Lead		
Barium		
Beryllium		
VOLATILES (ug/l)		
Methylene chloride	4.20	4.50
OTHER (ug/l)		
Total Hardness		
Total Organic Carbon		
Total Organic Halogens		
Chloride		

nondetect, then the background had no distribution and that analysis could not be run (in these cases, however, the contaminant was analyzed by risk assessment). As described above, if the Tail Area Probability was below 95%, then the null hypothesis was accepted and the sample was not considered to differ from background; however, if the Tail Area Probability was equal to or above 95%, then the null hypothesis was rejected and the sample was considered to be different from background.

12.4.0.5. Results of the tail area probability tests for surface water are summarized in Table 12.6. Barium, beryllium, and lead had positive hits in New River surface water samples and/or the Spring sample (SPG3). All of the background beryllium and lead samples, however, were nondetect, so no further analyses could be conducted for lead or beryllium. Barium had all detect values for the three background and the three downriver samples. Both sample NRSW4 and the spring sample SPG3SW1 exceeded the 95th percentile of the background distribution for barium, indicating that these samples contain significant levels of barium.

12.4.0.6. Results of the tail area probability tests for sediment are summarized in Table 12.7. Several analytes, including arsenic, barium, benzo (a) anthracene, beryllium, bis(2-ethyl hexyl) phthalate, chromium, chrysene, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, fluoranthene, lead, mercury, n-nitrosodiphenylamine, nickel, phenanthrene, pyrene, selenium, silver, and 2,4,6-trinitrotoluene, had positive hits in New River sediments. Arsenic, bis(2-ethyl hexyl) phthalate, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, mercury, n-nitrosodiphenylamine, and 2,4,6-trinitrotoluene were not detected in the background, so they could not be further analyzed. Tail area probability values were calculated for the other analytes. The 95th percentile of the background distribution was exceeded by sample SPG3SE1 for barium, beryllium, and silver; and by samples NRSW4 and SPG3SE1 for lead. This indicates that sediments from these samples contain significant levels of these contaminants.

12.4.0.7. The positive results and the chemicals of concern (COCs) as identified by the methods described in Section 6 are discussed below. However, the focus of the section is on the COCs identified as potential human health risks as detailed in the subsequent Risk Assessment sections.

TABLE 12. 6
New River Surface Water
Samples Exceeding Background
Radford Army Ammunition Plant

Field Sample Number	NRSW4	NRSW5	NRSW6	SPGSW1	Background Mean	95th Percentile of Background	95th Percentile of Background Exceeded?
METALS (ug/g)							
Barium	26.30	21.10	24.80	26.60	24.97	25.22	Yes

TABLE 12.7
New River Sediments
Samples Exceeding Background
Radford Army Ammunition Plant

Field Sample Number	NRSE4	NRSE5	NRSE6	SPG3SE1	Background Mean	95th Percentile of Background	95th Percentile of Background Exceeded?
METALS (ug/g)							
Barium	97.14	178.82	109.77	700.63	264.39	578.25	Yes
Beryllium	0.99	1.31		4.23	1.26	3.79	Yes
Chromium	37.53	31.50	24.89	62.70	51.85	104.59	No
Lead	4415.58	220.08	141.99	548.59	161.57	223.63	Yes
Nickel	13.25	15.82	12.49	52.98	27.53	77.48	No
Silver	0.10	0.10	0.11	0.22	0.13	0.19	Yes
SEMIVOLATILES (ug/g)							
Benz(a) anthracene			0.40	*	0.54	0.87	No
Chrysene			0.53	*	0.90	2.04	No
Fluoranthene	0.08		0.50	*	0.41	0.98	No
Phenanthrene			0.35	*	0.70	0.96	No
Pyrene			0.76	*	0.73	1.24	No

* Contaminants not analyzed for in this sample

12.4.1 Nature of Contamination

12.4.1.1 Sediment

12.4.1.1.1. Twelve COCs were identified in the sediment samples collected from the New River. They included the metals arsenic, barium, beryllium, lead, mercury, and silver, the SVOCs bis (2-ethyl hexyl) phthalate, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate, and n-nitrosodiphenylamine, and the explosive 2,4,6-Trinitrotoluene. Two compounds (arsenic and beryllium) were found at levels considered to be a potential human health risk. Of these, beryllium was identified as the risk driver for the New River sediment samples.

12.4.1.1.2. The explosive 2,4,6-TNT was only found in NRSE5 at 28.89 ug/g. Arsenic was found in this same sample at 6.92 ug/g and in SPG3SE1 at 17.40 ug/g. Beryllium was found in four sediment samples ranging from 0.99 ug/g in NRSE4 to 4.23 ug/g in SPG3SE1. Mercury was only detected in sample SPG3SE1 at 0.13 ug/g. Nickel was found in all the samples ranging from 12.49 ug/g in NRSE6 to 52.98 ug/g in SPG3SE1. The other positive results were in samples NRSE3 and NRSE5.

12.4.1.1.3. Barium was detected in all the sediment samples, ranging from 97.14 ug/g in NRSE4 to 700.63 ug/g in SPG3SE1. For the remaining metals COCs, the maximum results and sample are as follows: lead (4415.58 ug/g) in NRSE4 and silver (0.22 ug/g) in SPG3SE1. Chromium was detected in all of the New River sediment samples, but was not considered a COC because the downstream samples did not exceed background.

12.4.1.1.4. For the SVOC COCs, bis (2-ethylhexyl) phthalate, diethyl phthalate, dimethyl phthalate, di-n-butyl phthalate, and n-nitrosodiphenylamine were all detected only in the sample NRSE4. Other positive results were for selenium (found only in sample NRSE3 at 1.85 ug/g) and the SVOCs benzo[a]anthracene, chrysene, fluoranthene, phenanthrene, and pyrene. With the exception of fluoranthene, those SVOCs were all detected in samples NRSE1, NRSE2, NRSE3, and NRSE6. Fluoranthene was not found in NRSE1, but was found in NRSE4.

12.4.1.2 Surface Water

12.4.1.2.1. Barium, beryllium, and lead were the only COCs identified for the New River surface water samples. Of those, only beryllium was detected at levels considered to pose a potential threat to human health. Therefore, beryllium was identified as the risk driver for the surface water of the New River. Barium was found in all of the New River samples and in SPG3SW1. Concentrations ranged from 21.10 ug/l to 26.60 ug/l. The maximum detection was in sample SPG3SW1. Lead was found in samples NRSW4 and SPG3SW1. Beryllium was only detected in the SPG3SW1 sample at 1.64 ug/l.

12.4.2 Extent of Contamination

12.4.2.1 Sediment

12.4.2.1.1. NRSE5 was the only sample where 2,4,6-TNT was detected. It contains all of the metals listed as COCs except mercury. This sample was collected immediately downstream of SWMU 54 where 2,4,6-TNT was identified as a risk driver in the subsurface soils. NRSE4 had the highest lead concentration and contained all of the SVOC COCs. This sample was collected near SWMU 13 and downstream of where SWMU 48 potentially discharges groundwater.

12.4.2.1.2. The maximum beryllium (risk driver), arsenic, nickel, barium, chromium, mercury and silver detections were in sample SPG3SE1. This sample was collected from the spring which has been shown to be hydraulically linked to SWMU 17A. The spring discharge joins the New River at the sample location.

12.4.2.1.3. Samples NRSE1, NRSE2, and NRSE3 were collected upstream of the facility. However, NRSE3 had the only positive selenium detection and contained the second highest beryllium detection (3.03 ug/l). Many of the SVOC detected were from these three upstream samples.

12.4.2.2 Surface Water

12.4.2.2.1. SPG3SW1 contained most of the positive results for the New River surface water samples. It had the highest barium concentration and the only beryllium detection. This sample also contained lead, as did NRSW4. SPG3SW1 is hydraulically connected to SWMU 17A. NRSW4 was taken near SWMU 13 and SWMU 48.

12.5 CONTAMINANT FATE AND TRANSPORT

12.5.0.1. The environmental fate and transport of chemicals is dependent on the physical and chemical properties of the compounds, the environmental processes affecting them, and the media through which they migrate. Contaminants found in the sediments or surface water of the New River in the vicinity of RAAP are subject to transport downstream as dissolved constituents, particulates, or suspended solids. The dilution of any of these compounds is significant when considering distant downstream receptors.

12.5.0.2. The explosive compound 2,4,6-TNT was found in one of the sediment samples. Explosives have a high affinity for organic matter and low water solubility. In sediments, explosives tend to remain bound to the soil particles and dissolve slowly into the overlying water; no explosives were detected in any of the surface water samples. Movement of these compounds is usually controlled by the transport of particulates. Explosives are not readily bioaccumulated by living organisms. Metals identified as risk drivers or COCs for New River sediments would most likely mobilize as suspended sediments or possibly as dissolved ions.

12.5.0.3. Beryllium was the identified risk driver compound for the New River surface water. However, beryllium was only found in the spring sample (hydraulically connected to SWMU 17A). Barium and lead were identified as COCs. These metals could be mobilized as dissolved ions or as adsorbed constituents of the sediments.

12.6 RISK ASSESSMENT

12.6.0.1. The New River has not been classified as a SWMU within the RAAP boundaries. The river is being evaluated as the likely receptor of discharges from SWMUs to the surface water and sediment. In addition, connections have been established through a dye tracing study linking SWMU 17A to the New River. Surface waters are open to the atmosphere and therefore, contaminants that migrate to this medium may be transported to the atmosphere. The sediments in this area may fluctuate between being covered and uncovered with surface water; this does not limit the potential for emissions to the atmosphere and contaminants migrating sediments to surface waters and groundwater.

12.6.0.2. At present, use of the New River as a recreational water body and a drinking water source is expected to remain unchanged. All water used at RAAP is taken from the New River, from intakes located 2 miles upstream of Stroubles Creek and 6 miles downstream of Stroubles Creek. Water from the New River upstream of RAAP also supplies drinking water for the towns of Blacksburg and Christiansburg. Future uses of the New River are expected to remain consistent with current uses.

12.6.1 Summary of Chemicals of Potential Concern

12.6.1.0.1. The chemicals considered in the risk evaluation for New River surface water are three metals (barium, beryllium and lead). Chemicals considered for New River sediments include 6 metals (arsenic, barium, beryllium, lead, mercury, and silver) one explosive (2,4,6-trinitrotoluene) and five semivolatiles (bis(2ethylhexyl)phthalate, di-n-butyl phthalate, diethyl phthalate, dimethyl phthalate and n-diphenylnitrosamine).

12.6.1.1 Comparison to ARARs and TBCs for Groundwater and Soils

12.6.1.1.1. RAAP discharges approximately 25 million gallons per day (MGD) into the New River from 15 locations along the New River and Stroubles Creek. Effluent from RAAP consists of various treated process waters, wash waters, cooling waters, stormwater runoff and sanitary wastewater. The state water quality criteria establish a maximum allowed concentration for various parameters and these minimum standards are considered state ARARs. Federal water criteria are non-enforceable guidelines and they are considered TBCs for cleanup goals. Other TBC criteria considered for human health risk evaluation included reference doses (RfDs) and slope factors (SFs) from USEPA's Integrated Risk Information System and Health Effects Assessment Summary Table (USEPA, 1995a).

12.6.2 Exposure Assessment

12.6.2.1 Potential Pathways and Receptors

12.6.2.1.1. Current exposure pathways at the New River are considered to have a high probability of completion (site workers, construction workers, recreational users, fishermen). At present, recreational users and fishermen have access to the areas of the river characterized by surface water and sediment sampling. Current site workers have access to potentially contaminated surface waters and sediments during the course of their normal activities, since there are approximately 12 miles of shoreline within RAAP. Surface water from the New River is also used by RAAP for drinking water. However, exposure to contaminants through this exposure pathway are potentially incomplete because the surface water is treated prior to being used for domestic purposes. In addition, routine sampling is performed at the water treatment plant to ensure any potential chemicals in drinking water are within acceptable levels.

12.6.2.1.2. The conceptual site model summary for the New River is presented in Figure 12.2 and includes exposure routes, potential receptors and the medium containing potential contaminants of concern. All chemicals not eliminated by data validation were considered in the risk assessment for this body of water.

12.6.2.2 Exposure Point Concentrations and Chronic Daily Intakes

12.6.2.2.1. Exposure point concentrations for the three metals detected in New River (see Subsection 12.7.1) surface water are listed in Appendix I. These concentrations range from 0.000733 mg/L (beryllium) to 0.0246 mg/L (barium). Exposure point concentrations for the contaminants of concern in sediments (also see Section 12.7.1) range from 0.0936 ppm (mercury) to 701 ppm (barium).

12.6.3 Risk Characterization

12.6.3.0.1. The carcinogenic risk and hazard index were calculated for the surface water ingestion and dermal contact pathways (current site worker, recreational user, fisherman and construction worker) and sediment ingestion and dermal contact (current site worker). These calculations are presented in Appendix I. A discussion of the results of each pathway for non-carcinogenic and carcinogenic effects is presented below.

Figure 12.2
Conceptual Site Model for Current and Future Exposure Pathways
New River
Radford Army Ammunition Plant
Radford, Virginia

Primary Source	Release Mechanism	Receiving Medium	Exposure Route	Current Receptors: Site Workers	Current Receptors: Rec. Users	Current Receptors: Hunters, Fisherman	Current Receptors: Const. Workers	Future Receptor: Site Workers
RAAP Activities	Surface Runoff/ Groundwater Discharge	Surface Water and Sediment	Ingestion	X	X	X(F)	X	
			Inhalation					
			Dermal	X	X	X(F)	X	
	Tracking Deposition	Surficial Soils	Ingestion					
			Inhalation					
			Dermal					
	Leaching/ Deposition	Subsurface Soils	Ingestion					
			Inhalation					
			Dermal					
	Uptake	Biota	Ingestion			X(F)		
	Leaching	Groundwater	Ingestion					
			Inhalation					
			Dermal					

X = Pathways of potential concern
F = Fisherman scenario

12.6.3.1 Non-carcinogenic Effects

12.6.3.1.1. The calculated hazard indices for the site worker surface water and sediment ingestion and dermal contact exposure scenarios do not exceed acceptable levels. All calculated hazard indices are at least two orders of magnitude below acceptable levels.

12.6.3.1.2. The calculated hazard indices for the current recreational user and fisherman ingestion and dermal contact of surface water exposure scenarios also do not exceed acceptable risk levels. Again, the calculated hazard indices are at least two orders of magnitude below acceptable levels.

12.6.3.1.3. The calculated hazard indices for the construction worker surface water ingestion exposure scenarios do not exceed acceptable levels for CT and RME receptors. The hazard indices are at least two orders of magnitude below acceptable levels.

12.6.3.2 Carcinogenic Effects

12.6.3.2.1. The calculated cancer risks for the site worker sediment ingestion exposure scenario is within the target risk range primarily due to beryllium for RME receptors. Beryllium RME cancer risks for the ingestion exposure scenario are 1.27×10^{-6}. Beryllium was also found to have the highest cancer risks for the site worker dermal contact with sediments scenario, with calculated cancer risks for CT and RME receptors being 1.07×10^{-6} and 1.44×10^{-5}, respectively. Cancer risks for the site worker surface water ingestion and dermal contact scenarios are below the USEPA target risk range for RME receptors.

12.6.3.2.2. The calculated cancer risks for the recreational user surface water ingestion and dermal contact exposure scenarios are below the USEPA target risk range for CT and RME receptors. The calculated cancer risks for the fisherman dermal contact with surface water exposure scenario is within the USEPA target risk range for RME receptors, due to beryllium. Beryllium RME cancer risks for the dermal contact with surface water exposure scenario are 4.16×10^{-5}.

12.6.3.2.3. Construction worker cancer risks do not exceed the USEPA target risk range for ingestion and dermal contact with surface water. Calculated cancer risks are at least two orders of magnitude below the target risk range.

12.6.4 Uncertainty Analysis

12.6.4.0.1. Data collection/evaluation uncertainty may be relevant at the New River due to the types and numbers of samples collected. The New River flows through RAAP and receives point and non-point discharges from the plant. There are approximately 12 miles of New River shoreline within the boundaries of the plant. A limited number of surface water and sediment samples were used to characterize the river from areas related to suspected discharge points from SWMUs or other contaminated areas. This information may not be representative of the risk for the entirety of the river which flows through the plant, and therefore, the risk may be overestimated.

12.6.4.0.2. Standard default exposure values for recreational surface water users or fishermen have not been established by the USEPA as this is not a common exposure pathway that is examined in human health risk assessment. These pathways were quantified using exposure parameters based upon best professional judgment, which may over- or underestimate the representative risk for these two receptors.

12.6.4.0.3. Another area of uncertainty in evaluating human health risk from the New River is toxicity assessment. Oral and dermal slope factors are not available for some of the metals which were detected in surface water and sediment. Most studies are based on animal data and extrapolated to humans and also subchronic studies may be used assess chronic effects. In addition, extrapolations are characterized by uncertainty factors which can be as large as four orders of magnitude. This may tend to over- or underestimate risk.

12.6.4.0.4. The inhalation of volatiles and particulates from surface water and sediments may also be another source of uncertainty for the New River. This exposure scenario was not evaluated for current and future receptors in this area, due to the assumption that exposure times and contact rates would limit the potential completion of this pathway. This may tend to underestimate the risk for these exposure scenarios.

12.6.4.0.5. As with all modeled concentrations, there is a degree of uncertainty involved in assessing exposure scenarios. Fisherman ingestion of contaminated fish was evaluated by assessing uptake of contaminants present in surface water through normal activities. Using a bioconcentration factor, a simulated chemical concentration in fish tissue is derived. However, for the chemicals detected in New River surface water, bioconcentration information is limiting and the risks from this exposure scenario were not quantified. This may tend to underestimate the risk.

12.7 RISK SUMMARY

12.7.0.1. Carcinogenic risks and non-carcinogenic hazard indices were calculated for various receptors potentially exposed to multiple chemicals by various pathways in surface water and sediment. The risk calculations were summarized and are presented in Table 12.8. Under the NCP, the probability of excess cancers over a lifetime of exposure within or below USEPA's target risk range of 10^{-4} to 10^{-6} are considered to pose a low threat while a probability of excess cancers over a lifetime of exposures greater than 10^{-4} may pose an unacceptable threat of adverse health effects. For noncarcinogens, a hazard index below one is considered to pose a low threat of adverse health effects, while a hazard index greater than one may pose an unacceptable threat of adverse health effects.

12.7.0.2. All calculated hazard indices for all exposure pathways evaluated for New River are less than one by at least two orders of magnitude. These values indicate a very low potential for adverse noncarcinogenic health effects from this site.

12.7.0.3. Calculated total cancer risks for exposure pathways at the New River that are within the target risk range are fishermen and current site workers. All other exposure pathways examined are below the target risk range. These values indicate a potential for adverse carcinogenic health effects for the receptors mentioned above.

12.8 NEW RIVER SUMMARY

12.8.0.1 The New River is the most significant surface water feature within RAAP. The New River is the source of all water used at the facility; two intakes on the river are located within the facility boundaries. Industrial and domestic wastewaters are discharged into the river at locations within RAAP. Six surface water and sediment samples were collected from the river upstream of the facility or near likely discharge points of the four SWMUs investigated for the RFI to help characterize the river. Additionally, the spring determined to be hydraulically connected to SWMU 17A was included for discussion in this section since it discharges directly to the river.

Table 12.8
Summary of Human Health Risk
New River
Radford Army Ammunition Plant

Receptor	Pathways	HI CT	HI RME	Cancer Risk CT	Cancer Risk RME
Site Worker	Ingestion of Surface Water	0	0	1.10E-08	1.10E-07
	Dermal Contact with Surface Water	0	0	2.77E-09	3.73E-08
	Ingestion of Sediment	0.01	0.02	1.58E-07	3.16E-06
	Dermal Contact with Sediment	0.01	0.02	1.10E-06	1.47E-05
Total for Site Worker		0.02	0.04	1.27E-06	1.80E-05
Fisherman	Ingestion of Surface Water	0	0	2.54E-10	5.07E-08
	Dermal Contact with Surface Water	0	0	1.60E-07	4.16E-05
Total for Fisherman		0	0	1.60E-07	4.17E-05
Construction Worker	Ingestion of Surface Water	0	0	5.50E-09	4.40E-08
	Dermal Contact with Surface Water	0	0	1.04E-08	5.42E-08
Total for Construction Workers		0	0	1.59E-08	9.82E-08
Recreational User	Ingestion of Surface Water	0	0	3.09E-11	2.03E-09
	Dermal Contact with Surface Water	0	0	1.20E-09	9.28E-08
Total for Recreational User		0	0	1.23E-09	9.48E-08

12.8.0.2. Beryllium was determined to be the risk driver compound for New River sediment. Numerous metals and 2,4,6-TNT were categorized as COCs (2,4,6-TNT was only found in the sample just downstream of SWMU 54). Several SVOC COCs were detected in various sediment samples, including the upstream samples. Beryllium was identified as the risk driver compound in the New River surface water. Barium was found in all the samples; the maximum detection was in the spring sample. Beryllium was only detected in the spring sample. In general, the spring sediment and surface water sample contained maximum concentrations of most of the COCs identified for the river.

12.8.0.3. The human health risk assessment indicated a potential for carcinogenic adverse human health effects for ingestion and dermal contact of surface water and sediment for site workers and fishermen.

SECTION 13

RECOMMENDATIONS

13.0.0.1 The following recommendations are based on an evaluation of all site characterization data collected during the RFI and the human health risks determined to be associated with each SWMU or area of concern. The rationale for each recommendation considers the nature of observed releases and adverse human health effects, and the practical aspects of an active facility. Table 13.1, which is included at the end of the section, presents a summary of the the human health risks, contaminants of concern, and the recommendations that have been derived from them. The human health risk concerns were determined by the methods described in Section 6; detailed descriptions of the risk analyses are provided in the risk assessment subsection of each SWMU or area of concern.

13.1 SWMU 17/40 (CONTAMINATED WASTE BURNING AREAS AND SANITARY LANDFILL)

13.1.1 Recommendations

1) Recommendation: Interim Measures

The human health risk assessment indicates a potential for noncarcinogenic and carcinogenic adverse human health effects for ingestion and dermal contact of surface and subsurface soils and groundwater. The dye tracing study demonstrated a subsurface connection between SWMU 17 and the New River; chemicals of concern found at SWMU 17 were also detected at the discharge point, indicating a release of contaminants. Surface and near surface contamination of soils in areas of active operations indicates the need for interim measures to control potential threats to the health of site workers.

Interim measures are intended to control or abate threats to human health while long term solutions are developed or implemented. The interim measures recommended, which would be classified as non-emergency actions, would consist of the implementation of relatively simple engineering controls to prevent or minimize dermal contact with surface soils, including: protective clothing (appropriate gloves and coveralls) and wash stations at easily accessible locations.

2) Recommendation: Conduct Corrective Measures Study (CMS)

A CMS is recommended to address long term solutions to contaminant migration from SWMU 17. Since the active operations represent a continuing source of contamination to the soils and groundwater, corrective measures should be developed which can mitigate contaminant releases while minimizing the impact to the active operations. Such corrective measures might include:

- Construction of a concrete pad with appropriate drainage controls for all burning operations;

- Construction of an impermeable cap to prevent infiltration of precipitation and reduce contaminant flushing; and

- Excavation of the shallow fill materials and installation of an impermeable liner to abate future contaminant migration.

The objective of the CMS is to identify and develop proposed corrective measures and alternatives by screening available technologies, assessing site conditions, and examining financial, institutional, and health impacts. A CMS would justify the recommended corrective actions on a technical, environmental and human health basis, including applicable cleanup levels. The CMS would provide complete information on the status of remediation activities and establish a system for regular reporting, record keeping, and compliance requirements. Finally, the CMS would provide sufficient information so that remedial design and implementation could proceed.

13.2 SWMU 31 (COAL ASH SETTLING LAGOONS)

13.2.1 Recommendations

1) Recommendation: Collect Additional RFI Data

The human health risk assessment indicates a risk based on the hypothetical future site worker groundwater usage scenario. However, migration of metals from the coal ash lagoon sediments to the groundwater and eventually to the New River appears to be occurring. Since the lagoon sediments were only sampled for TCLP waste disposal characterization during the RFI, they could not be considered in the human health risk assessment. Although the previous investigation included sediment sampling data, this information could not be fully assessed for human health risks. Additionally, the compositing procedure used in the previous investigation to collect the samples may not have been appropriate to characterize the sediments. Therefore, additional sampling is recommended to define the nature and extent of contamination at SWMU 31.

Based on the available sampling data, a "No Further Action" recommendation would be inappropriate. However, sampling of the sediments, coupled with the additional sampling of the New River, would allow for risk assessment of the sediment pathway and may provide sufficient information to support a "No Further Action" recommendation. The sediments should be sampled for TAL metals; a minimum of two additional New River sediment and surface water samples should be collected along the area of likely groundwater discharge from SWMU 31.

Should the supplemental data demonstrate a significant release of contaminants to the groundwater and the New River, the following action alternatives should be considered:

- Elimination of the discharge of filter backwash and drinking water overflow to the lagoons. The discharge to the lagoons is a flushing mechanism which facilitates the migration of metals from the sediments to the groundwater; and

- Closure of SWMU 31 through excavation of sediments and backfilling of the lagoons.

13.3 SWMU 48 (OILY WASTEWATER DISPOSAL AREA)

13.3.1 Recommendations

1) Recommendation: Perform Dye Tracing Study

Better definition of the groundwater flow at the SWMU 48 area and identification of specific discharge points are necessary to fully evaluate site conditions in this vicinity. Therefore, a dye tracing study is recommended for the SWMU 48 area. Although this study would not necessarily identify the source of VOCs found in the SWMU 48 and SWMU 13 groundwater, it would help to quantify risk analysis by defining the pathways of contaminant migration. The study would also provide useful groundwater characterization information for SWMUs 13, 16, 27, 28, 29, 30, 50, 51, 52, 53, and 59.

2) Recommendation: Access Restriction/Surface Water Runoff Drainage Control

Human health risk analysis suggests the potential for carcinogenic adverse human health effects for ingestion and dermal contact with surface soils (the most significant surface soil contamination appears to be from the upper disposal mound). However, the risk analysis determined that the inhalation of particulates pathway is not a concern. Therefore, restriction of access by installing a fence around the upper oily waste disposal mound at this SWMU is recommended to minimize contact with surface soils. Construction of surface water drainage controls will minimize the potential for contaminant migration through runoff.

13.4 SWMU 54 (PROPELLANT ASH DISPOSAL AREA)

13.4.1 Recommendations

1) Recommendation: Conduct Corrective Measures Study (CMS)

Risk analysis indicates the potential for noncarcinogenic and carcinogenic adverse human health effects for dermal and ingestion exposure scenarios for subsurface soils and groundwater. 2,4,6-TNT and other chemicals of concern identified for SWMU 54 were also found in New River sediments indicating contaminant migration. One of the waste ash composite samples exceeded the TCLP regulatory limit for lead; the ash is at the surface in places and SWMU 54 is prone to flooding which may transport contaminants to downstream receptors. Additionally, this area is not within the facility security fence and is accessible from the New River. Therefore, a CMS is recommended to define methods of source remediation.

The objective of the CMS is to identify and develop proposed corrective measures and alternatives by screening available technologies, assessing site conditions, and examining financial, institutional, and health impacts. A CMS would justify the recommended corrective actions on a technical, environmental and human health basis, including applicable cleanup levels. The CMS would provide complete information on the status of remediation activities and establish a system for regular reporting, record keeping, and compliance requirements. Finally, the CMS would provide sufficient information so that remedial design and implementation could proceed.

13.5 STROUBLES CREEK

13.5.1 Recommendations

1) Recommendation: Additional Sampling

Risk analysis suggests a low potential for carcinogenic adverse human health effects for dermal and ingestion exposure scenarios for sediments and for dermal exposure scenarios for surface water. However, since contaminants were found in the sample taken upstream of RAAP, and since only two samples were collected, additional work is required to fully characterize the creek. All potential sources contributing to the quality of Stroubles Creek have not been investigated. Additional sampling may indicate contaminant sources unrelated to activities at RAAP. Complete characterization of the creek should include a detailed analysis of the effects of dilution on the contaminants.

13.6 NEW RIVER

13.6.1 Recommendations

1) Recommendation: Additional Sampling

Risk analysis suggests the potential for carcinogenic adverse human health effects for dermal and ingestion exposure scenarios for sediments and for dermal exposure scenarios for surface water. However, since sample locations were chosen to correspond to the likely discharge point of the four SWMUs investigated for this report, the possible impacts of other SWMUs or permitted outfall discharges to the river have not been fully explored. Therefore, additional work is necessary to completely characterize the river. Additional sampling of the river may provide essential information for quantifying pathways at specific SWMUs as the basis of further action. The sampling may also indicate contaminant sources unrelated to activities at RAAP. Complete characterization of the river should include a detailed analysis of the effects of dilution on the contaminants.

TABLE 13.1
SUMMARY OF RFI RECOMMENDATIONS
RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

SWMU or Area of Concern	HUMAN HEALTH RISK CONCERNS[1]									RECEPTORS			Risk Driver Compounds[3]	Recommendation
	Ingestion			Dermal Contact			Inhalation							
	GW	SW/SE	Soil	GW	SW/SE	Soil	GW	SW	Soil	Site Worker	Const. Worker	Rec. Users[2]		
SWMU 17/40: Contaminated Waste Burning Areas and Sanitary Landfill	✓		✓	✓		✓				Soil (I) Soil (D) GW (I) GW (D)	Soil (I) Soil (D)	H-Soil (I) H-Soil (D)	Antimony and Beryllium (GW); Arsenic and Beryllium (Surface Soil); Antimony and Arsenic (Subsurface Soil)	Conduct Corrective Measures Study Interim Measures
SWMU 31: Coal Ash Settling Lagoons	✓			✓						GW (I) GW (D)			Antimony and Beryllium (GW)	Collect Additional RFI Data
SWMU 48: Oily Wastewater Disposal Area	✓		✓	✓		✓	✓			Soil (I) Soil (D) GW (I) GW (D) GW (IH)	Soil (I) Soil (D)	H-Soil (I) H-Soil (D)	Beryllium and Carbon Tetrachloride (GW); Arsenic and Beryllium (Surface Soil)	Perform Dye Tracing Study Access Restriction/Surface Water Runoff Drainage Control
SWMU 54: Propellant Ash Disposal Area	✓		✓	✓		✓				GW (I) GW (D)	Soil (I) Soil (D)		Antimony, Arsenic and Beryllium (GW); Mercury and 2,4,6-Trinitrotoluene (Subsurface Soil)	Conduct Corrective Measures Study
Stroubles Creek		✓			✓					SE (I) SE (D)		F-SW (D)	Beryllium (SW); Arsenic and Beryllium (SE)	Additional Sampling
New River		✓			✓					SE (I) SE (D)		F-SW (D)	Beryllium (SW); Beryllium (SE)	Additional Sampling

1 - For compounds with hazard indices >1 or cancer risks > 1×10^{-6}

2 - F = fisherman, H = hunter, R = recreational surface water user.

3 - Risk driver compounds are discussed in the risk assessment subsections of Sections 7 - 12 of this report.

(I) - Ingestion
(D) - Dermal
(IH) - Inhalation
(SE) - Sediment
(SW) - Surface Water
(GW) - Groundwater

G:\JOBS\722\722843\TBLES-1.XLS

SECTION 14

REFERENCES

Bartholomew, M.J. and Lowery, W.D., 1979, Geology of the Blacksburg Quadrangle, Virginia: Virginia Division of Mineral Resources Publication 14, text and 1:24,000 scale map.

Bollinger, G.A. and Wheeler, R.L., 1983, Giles County, Virginia, Seismic Zone: Science, v. 219, p. 1063-1065. .

Bollinger, G.A. and Wheeler, R.L., 1988, The Giles County Virginia, Seismic Zone-Seismological results and geologic interpretations: U.S. Geological Survey Professional Paper 1355, 85p.

Bouwer, H. and R.C. Rice, 1976. A Slug Test Method For Determining Hydraulic Conductivity of Unconfined Aquifers With Completely or Partially Penetrating Wells, Water Resources Research, Vol. 12, No. 3, pp. 423-428.

Charles T. Main of Virginia, Inc., 1988, Preliminary Hydrogeologic Investigation for Ash Landfill permit Application. Prepared for the Army Corps of Engineers, Revised 1989.

Dames & Moore, 1992a. Draft RFI Report for the Radford Army Ammunition Plant. Prepared for the U.S. Army Toxic and Hazardous Materials Agency.

Dames & Moore, 1992b. Draft VI Report for the Radford Army Ammunition Plant. Prepared for the U.S. Army Toxic and Hazardous Materials Agency.

Engineering-Science, Inc., (ES), 1994a. RCRA Facility Investigation for Solid Waste Management Units 17, 31, and 48 and Corrective Measures Study Work Plan for SWMU 54 at Radford Army Ammunition Plant, Radford, Virginia.

Engineering-Science, Inc. (ES), 1994b. Dye-Tracing Study Report, Radford Army Ammunition Plant. Prepared for U.S. Army Environmental Center.

Engineering-Science, Inc. (ES), 1994c. Quality Assurance Project Plan to Support FRI/CMS Activities at Radford Army Ammunition Plant. Prepared for U.S. Army Environmental Center.

Engineering-Science, Inc. (ES), May 1993. Dye-Tracing Study Work Plan Radford Army Ammunition Plant. Prepared for U.S. Army Environmental Center.

Freeze, R.A. and J.A. Cherry, 1979. Groundwater. Prentice Hall, Inc., New Jersey.

Hem, J.D., 1985. *Study and Interpretation of the Chemical Characteristics of Natural Water*. U.S. Geological Survey Water-Supply Paper 2254.

Howard, A.B., and Howard, B.Y., 1967, Solution of Limestone Under Laminar Flow Between Parallel Boundaries, Caves and Karst v. 9, p. 25-38.

New River Health District, Verbal and Written Personal Communications, 1995.

New River Valley Planning District Commission (NRVPDC), 1994. Virginia's New River Valley Regional Databook.

Office of Deputy Assistant Secretary of Defense (Environment), 1992. User's Manual for the Defense Priority Model.

Palmer, A.N., 1990, Groundwater Processes in Karst Terranes in Groundwater Geomorphology, Geological Society of America Special Paper #252. ed. C.G. Higgins and D.R.Coates.

Palmer, A.N., 1984, Geomorphic Interpretation of Karst Features in LaFleur, R.G., ed. Groundwater as a Geomorphic Agent.

Parsons Engineering Science, Inc. (Parsons ES), June 1995. Revised Addendum to the Final RCRA Facility Investigation Work Plan, Radford Army Ammunition Plant, Radford, Virginia.

Quinlan, J.F., Special Problems in Groundwater Monitoring in Karst Terranes: Groundwater and Vadose Zone Monitoring, ASTM STP 1053, D.M. Nielsen and A.I. Johnson, Eds., American Society for Testing and Materials, Philadelphia, 1990, pp 275-304.

Schultz, A.P., Geologic Map of the Radford North Quadrangle: Virginia Division of Mineral Resources (VDMR) open file in preparation.

Schultz, A.P., 1988, Horses in Fensters of the Pulaski Thrust Sheet, Southwestern Virginia: Structure, Kinematics, and Implications for Hydrocarbon Potential of the Eastern Overthrust Belt. U.S. Geological Survey Bulletin, 1989.

Schultz, A.P., 1986a, Max Meadows tectonic Breccia at Pepper, Virginia: Geological Society of America Centennial Field Guide-Southeastern Section.

Schultz, A.P., 1986b, Broken Formations of the Pulaski Thrust Sheet Near Pulaski, Virginia: Virginia Polytechnic Institute and State University, Department of Geological Sciences, Memoir Series.

Schultz, A.P. , 1983, Broken-formations of the Pulaski thrust sheet near Pulaski, Virginia: Blacksburg, Virginia, Virginia Polytechnic Institute and State University, Ph.D. dissertation, 99p.

Schultz, A.P. and Southworth, C.S., 1989, Large bedrock landslides of the Appalachian Valley and Ridge province of eastern North America, *in* Schultz, A.P., and Jibson, R.W., eds., Landslides processes of the eastern United States and Puerto Rico: Geological Society of America Special Paper 236, p. 57-74.

Soil Conservation Service (SCS), 1985a. Soil Survey of Pulaski County, Virginia. U.S. Department of Agriculture.

Soil Conservation Service (SCS), 1985b. Soil Survey of Montgomery County, Virginia. U.S. Department of Agriculture.

Stumm, W. And Morgan J. J., 1981. Aquatic Chemistry, John Wiley & Sons.

U.S. Army Environmental Hygiene Agency (USAEHA), July 1994. Receiving Water Biological Study No. 32-24-H1SM-94. Radford Army Ammunition Plant, Radford, Virginia.

U.S. Army Environmental Hygiene Agency (USAEHA), 1987. Hazardous Waste Study No. 37-26-0785-88, Soil Sampling Study at the Radford Army Ammunition Plant Open Burning Ground, Radford Army Ammunition Plant, Radford, Virginia.

U.S. Army Environmental Hygiene Agency (USAEHA), 1981. Army Pollution Abatement Study, Installation of Monitoring Wells, Radford Army Ammunition Plant, Radford, Virginia (USAEHA No. 81-26-8252-81).

U.S. Army Environmental Hygiene Agency (USAEHA), 1980. Hazardous Waste Management Survey No. 39-26-0134-82, Radford Army Ammunition Plant, Radford, Virginia.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1987. Geotechnical Requirements for Drilling, Monitoring Wells, Data Acquisition, and Reports.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1984. Installation Reassessment of Radford Army Ammunition Plant, Radford, Virginia, Report No. 103R.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), 1976. Installation Assessment of Radford Army Ammunition Plant, Records Evaluation Report No. 103.

U.S. Department of Energy, May 1993. RCRA Corrective Action Program Guide, (Interim).

U.S. Environmental Protection Agency (USEPA), 1995a. Integrated Risk Information System (IRIS). Database. Office of Research and Development.

U.S. Environmental Protection Agency (USEPA), 1995b. Health Effects Assessment Summary Tables (HEAST). Annual FY-1993. OHEA ECAO-CIN-909. March 1993.

U.S. Environmental Protection Agency (USEPA), 1994. Memorandum Concerning Risk-Based Concentration Table, First Quarter 1994. From Roy L. Smith, PhD., Senior Toxicologist, Technical Support Section to RBC Table mailing list. January 7, 1994.

U.S. Environmental Protection Agency (USEPA), 1993. *Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure.* Draft.

U.S. Environmental Protection Agency (USEPA) 1992a, Installation Assessment, Radford Army Ammunition Plant, Radford, Virginia. Environmental Photographic Interpretation Center (EPIC).

U.S. Environmental Protection Agency (USEPA) 1992b. Statitcal training Course for Ground-water Monitoring Data Analysis, EPA530-R-93-003.

U.S. Environmental Protection Agency (USEPA), 1992c. Supplemental Guidance to RAGS: Calculating the Concentration Term.

U.S. Environmental Protection Agency (USEPA), 1991. Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual Part B. Development of Risk-based Preliminary Remediation Goals. Office of Solid Waste and Emergency Response. OSWER Directive 9285.7-01B. 13 December 1991.

U.S. Environmental Protection Agency (USEPA), 1990. National Oil and Hazardous Substances Contingency Pollution Contingency Plan, Final Rule. Fed. Reg. 55:8666-88-65. March, 1990.

U.S. Environmental Protection Agency (USEPA), 1989a. Draft Permit for Corrective Action and Incinerator Operation, Radford Army Ammunition Plant, Radford, Virginia, VA1-21-002-0730.

U.S. Environmental Protection Agency (USEPA) 1989b. Statitcal Analysis of Ground-water Monitoring Data at RCRA Facilities, Interim Final Guidance.

U.S. Environmental Protection Agency (USEPA), 1989c. Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual Part A. Interim Final. Office of Emergency and Remedial Response. EPA/540/1-89/002.

U.S. Environmental Protection Agency (USEPA), 1988. CERCLA Compliance with Other Laws Manual. EPA/540/6-89/006.

U.S. Environmental Protection Agency (USEPA), 1987. RCRA Facility Assessment of Radford Army Ammunition Plant, Radford, Virginia.

Virginia State Climatological Office, Verbal and Written Personal Communications, 1995.

Washington Post, April 4, 1995. Article on the Vultures at Radford Army Ammunition Plant, Radford, Virginia.

White, W.B., 1990. Surface and Near-Surface Karst Landforms in Groundwater Geomorphology, Geological Society of America, Special Paper #252. ed. C.G. Higgins and D.R. Coates.